THE COAST SCENERY OF NORTH DEVON

Smoothlands, from Titchberry Water Mouth (Hartland District), looking South.

[*Frontispiece*

THE COAST SCENERY
OF
NORTH DEVON

BEING AN ACCOUNT OF THE GEOLOGICAL FEATURES OF THE COAST-LINE EXTENDING FROM PORLOCK IN SOMERSET TO BOSCASTLE IN NORTH CORNWALL

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ILLUSTRATED BY SEVENTY PHOTOGRAPHS, TWELVE TEXT-FIGURES AND TWO MAPS

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TO

MY MOTHER

PREFACE

For many years past I have been engaged on research, chiefly of a palæobotanical nature, on the Carboniferous and Devonian rocks of North Devon and Cornwall. My attention, for various reasons which need not be entered into here, has been chiefly confined to the coast-line, the magnificent cliffs of which stretch, almost without a break, from Porlock in Somerset to Boscastle in North Cornwall. Though the rocks and fossils of the Devonian of North Devon are very well known, I have been surprised to find how little this coast has been explored as yet from the point of view of the geology of its scenery. I believe I am the first who has ever examined geologically the long stretch of cliffs, consisting of Carboniferous rocks, from end to end and in detail, though many have visited some of its nooks and crannies for the sake of their scenery. Yet, so far as I am aware, no geological description of this coast-line as a whole exists, and such information as has been published has been meagre, and sometimes unworthy of the subject. In my own case, I have been astonished to find how much more interesting this coast really is than the literature on the subject

had led me to expect; so much so that I have been led away from the beaten paths of fossil botany to explore some of its undescribed wonders, and to engage in more strictly geological studies than I originally anticipated.

It has occurred to me that a general account of the geology of the scenery of this coast-line, expressed in as simple a language as possible, might interest those who visit North Devon and North Cornwall. Each year sees an increasing throng of visitors to this sea-board, and recently the growth in the number of those who penetrate into the wilder country of West Devon, still remote from the railway, appears to be especially marked. I have found, myself, that an understanding, however imperfect, of the special peculiarities of the geology of a particular locality has greatly added to the pleasure of a visit to it, and I fancy this may be also the case with others.

It has not been my intention, however, to attempt here either a geological text-book or a guide-book pure and simple. If possible I desire that this volume should be readable, and of use to visitors who are interested in geology, in a greater or less degree. Since, however, the area which it embraces is so large, including, as it does, more than one hundred miles of coast-line, it has seemed imperative to subdivide it into districts, and this plan will, I hope, be of convenience to the reader.

In the Introduction the main points of interest in the geology of this coast-line are enumerated, and the geologist will, I trust, overlook the elementary nature of much of the information which is there contained, in favour of those who have not previously paid attention to the science. The latter will, I hope, master the meaning of the few technical terms necessary to understand the subject, such as dip and anticline, by reading Appendix I at an early stage.

The book is divided into two parts. In Part I, each of the six districts, into which the whole area is subdivided, is described in detail. It is assumed that the reader may wish to make a more or less thorough examination of one or more of these districts, and for this purpose directions are included as to the most convenient headquarters, and how best to reach the more interesting localities.[1] It is not to be supposed that it is easy, in all cases, to reach the places of which photographs are included here. In many instances this is far from being true, and therein lies one of the great charms of this coast. To know it thoroughly, and to explore its wonders, considerable activity and skill are required, as will be pointed out in the Intro-

[1] This information is intended to be supplementary to that which the Tourist will find in any of the excellent guides to this coast, such as Ward's *North Devon and North Cornwall* (Baddeley and Ward's Thorough Guide Series), which has most useful maps.

duction. In Part II, a fuller treatment will be found of some of the special points of geological interest presented by this coast-line, particularly the evolution of coastal waterfalls, the sea-dissected valleys and the marine denudation of inclined and folded rocks. So far as I am aware, these are for the most part new contributions to the science.

Geologists may probably not agree with all the conclusions here expressed, but it will, I hope, be remembered that this is pioneer work in a strange land, and even if the subject gives rise to controversy, my purpose will be served if I have been able to call attention to points of interest hitherto overlooked.

This volume is intended to deal solely with the nature and origin of the coast scenery. For this reason no special or detailed account of the rocks or their fossils is attempted. An exception has, however, been made in cases where important localities for fossils, whether animal or plant, lie actually on the coast-line or within sight of the sea, and it is hoped that this information will be of service to those who wish to combine a study of the characteristic fossils with experience of the coast scenery. On the other hand, the temptation to include some references to famous localities, which lie a little inland, has had to be resisted, on account of the exigencies of space. Further information on these subjects will, however, be found

in the memoirs included in the bibliography (Appendix II), where reference to all the more important geological papers on the whole district is given.

For the photographs which illustrate this volume I must plead responsibility. If they fall short of what they should be, I can only hope that the difficulties of photographing on a narrow strip of shore, piled high with great boulders, and of necessity so close to high cliff sections as to try the patience of both a "rising front" and a short-focus lens, may not be forgotten. In this connection I would express my gratitude to Mr. D. G. Lillie, B.A., of St. John's College, Cambridge, the constant companion of my explorations in Devonshire during many years past, for the noble way in which he has borne more than his share of the labour of dragging a heavy stand-camera up and down steep cliffs and along beaches of the roughest description.

I am also greatly indebted to Mr. Lillie for much help in other directions, and especially for drawing one of the maps and two of the text-figures. Some years ago we decided to study, together and conjointly, the fine series of cliff waterfalls exhibited by these coasts. When we had completed our task, we found that it had grown under our hands to such an extent, that the limits of an ordinary memoir would be quite

inadequate to do justice to the subject. An opportunity has been found here of expressing these results. I would wish to make it quite clear that Mr. Lillie is entitled to at least a half share in whatever scientific merit may attach to the observations concerning these waterfalls. We are entirely agreed as to the facts and the conclusions, but, in the absence of my colleague in the Antarctic, the onus of describing them rests with me alone, and I must acknowledge undivided responsibility for the other matters here discussed. I have endeavoured, though no doubt imperfectly, to do justice to the subject, and to my colleague's observations.

To my wife, I am indebted for much help in the field, and in passing this book through the press, and especially for drawing many of the text-figures.

I have also to record my grateful thanks to many, resident in Devonshire, who have aided my work there for some years past in various ways, for their continued interest and help. My indebtedness to Mr. Inkermann Rogers of Bideford, for assistance in the study of the Carboniferous and Devonian rocks, has been already expressed elsewhere, and I have pleasure in emphasizing it here. Though Mr. Rogers has not been so directly concerned with my studies of the coast scenery, as with the researches on the fossil floras of these

rocks, he has obtained for me, with his wonted willingness and resource, much information on certain points, for which I owe him many thanks. I would also acknowledge my indebtedness to Mr. Vidal of Barnstaple, and Dr. Young of Woolacombe, among others, who have in the kindest possible way placed their special knowledge of portions of the coast-line at my service.

Finally, to my friend and colleague, Mr. Henry Woods, F.G.S., University Lecturer in Palæozoology, I am indebted for a revision of the names of the Devonian fossils mentioned in the text.

E. A. Newell Arber.

The Sedgwick Museum of Geology,
Cambridge, *March 2nd*, 1911.

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COAST SCENERY OF NORTH DEVON

INTRODUCTION

THE coast-line, with which we are concerned in this volume, includes the whole of that of North and West Devon, a small part of West Somerset, and a considerable portion of the North Cornish coast. In other words, it is the coast-line of the area occupied by the Devonian succession of North Devon and the Carboniferous rocks, the geological boundaries of which do not coincide with those of the counties (Map No. 2). Each of the six districts, into which the whole region will be subdivided, has features peculiar to itself, in addition to others which it shares with its neighbours. The Lynton District, stretching from Porlock to Woody Bay, and that of Ilfracombe (from Woody Bay to Lee near Ilfracombe) are quite distinct in the character of their cliff scenery from the coasts of West Devon and North Cornwall. The Mortehoe District (from Lee to Braunton Burrows), though from the point of view

of its scenery decidedly tamer than the two first-named districts, is perhaps of more varied geological interest than either. The coasts of the Clovelly and Hartland Districts, stretching from Westward Ho! to Hartland Point, and then southwards to Bude, contain the wildest and grandest cliffs in the whole area, quite distinct in their structure from those of Lynton or Ilfracombe. The last subdivision, the Boscastle District (from Bude to Boscastle) is well known as one of the most varied stretches of coast-line in West Cornwall.

We shall here consider each of these districts in turn, but it may be well, in the first place, to call attention to the general geology of the whole area, and to the chief types of cliff scenery which occur within its boundaries.

THE GENERAL GEOLOGY OF THE AREA.

The character of the cliff scenery of a coastline depends, partly on the geological nature of the rocks, which are being eaten into by the sea, and partly on the configuration and elevation of the land, which the sea is attacking. It is obvious that a mountain, partly washed by the sea, such as the Great Hangman, gives rise to an entirely different type of coast scenery from a flat, alluvial plain, sloping gently to the coast from a point some miles inland. Again, the effect of sea erosion on

Plate I

A low anticlinal fold near Hartland Quay (Hartland District).

[To face p. 2

cliffs which are built up of sandstones, or of alternating beds of sandstones and shales, differs in a remarkable degree from that produced on a series of slates.

There are only three main types of rock which are at all common in the area: sandstones, which vary enormously in their characters, with all gradations from coarse grits and sandy flags to fine-grained sandstones; shales or stratified hardened muds, equally varied as regards their physical characters; and, in the Devonian sequence, slates, which are metamorphosed, cleaved shales. Limestones are rare and unimportant as land-builders, though impersistent bands, of no great thickness, occur in the Devonian and the Upper Carboniferous districts. There are practically no igneous rocks of any sort to be seen along this coast. In this respect the Devonian of North Devon is strongly contrasted with that of South Devon, where igneous rocks are well represented. Triassic marls occur only at one spot on the shores of Bideford Bay, at Peppercombe. Glacial deposits, or Boulder Clays, are completely absent from the whole area, though a few interesting erratic blocks, of igneous origin, are known. There are, inland, certain beds of clay, no doubt representing old lake deposits, of uncertain geological age, but these are distant from the coast-line.

The geological structure of the whole area is,

in general, quite simple. It is a basin-like trough, or simple fold, as is shown in Fig. 1, which is a section across Devon from North to South.

The rocks are of Palæozoic age, and belong to two great geological formations, the Devonian and the Carboniferous. The Devonian series forms the lower portion of the fold, and, in North Devon, on the north side of the basin, these beds come to

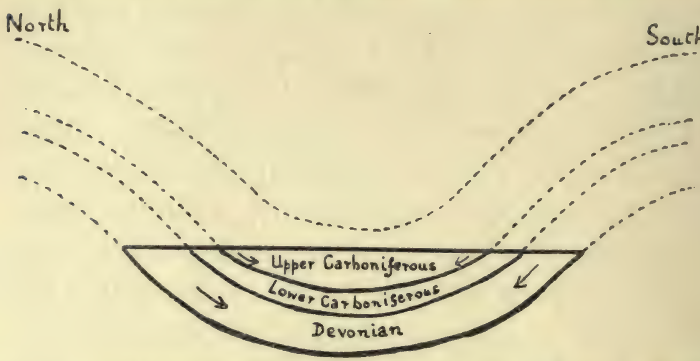


FIG. 1.—Diagrammatic section across Devonshire and Cornwall from North to South. The dotted lines indicate roughly the amount of rock removed by aërial denudation.

the surface, and occupy the whole of the country north of a line drawn, due east and west, through the estuary of the Torridge and the Taw.[1] Thus the coast-lines of the Bristol Channel and part of Bideford Bay, from Porlock in Somerset to Braunton Burrows in North Devon on the northern side of the above-mentioned estuary (Map No. 2),

[1] This is roughly the line of the Great Western Railway from Taunton to Barnstaple.

consist of Devonian rocks. These beds are known to geologists as the North Devon Devonian, to distinguish them from the series, in South Devon, on the southern side of the basin (Fig. 1), which is quite dissimilar. We are not, however, concerned with this southern series here.

In Central and West Devon, and also in North Cornwall, the Devonian rocks are overlain by a considerable thickness of younger rocks of Carboniferous age. The lower portion of this series, the Lower Carboniferous (known locally in Devonshire as the Lower Culm Measures) is not seen in the coast section in North Devon, but, on the Southern side of the basin (Fig. 1), these beds constitute the bold cliff scenery of the neighbourhood of Boscastle (Map No. 2). The beds, which occupy the highest position in the trough, are the Upper Carboniferous or Upper Culm Measures, which extend from the estuary of the Torridge and the Taw southward to near Boscastle in Cornwall.[1]

Thus, of our six districts, we see that the first three consist of Devonian rocks, while the Clovelly and Hartland Districts are formed of Upper Carboniferous sediments, and the Boscastle District, partly of Upper, and partly of Lower Carboniferous deposits. It will be noticed in Fig. 1 that the

[1] The Upper Carboniferous rocks are subdivided by Mr. Ussher into Middle and Upper Culm Measures on purely lithological grounds.

beds on the northern and southern margins of the basin are inclined or *dip* in towards the centre, where they become almost horizontal.

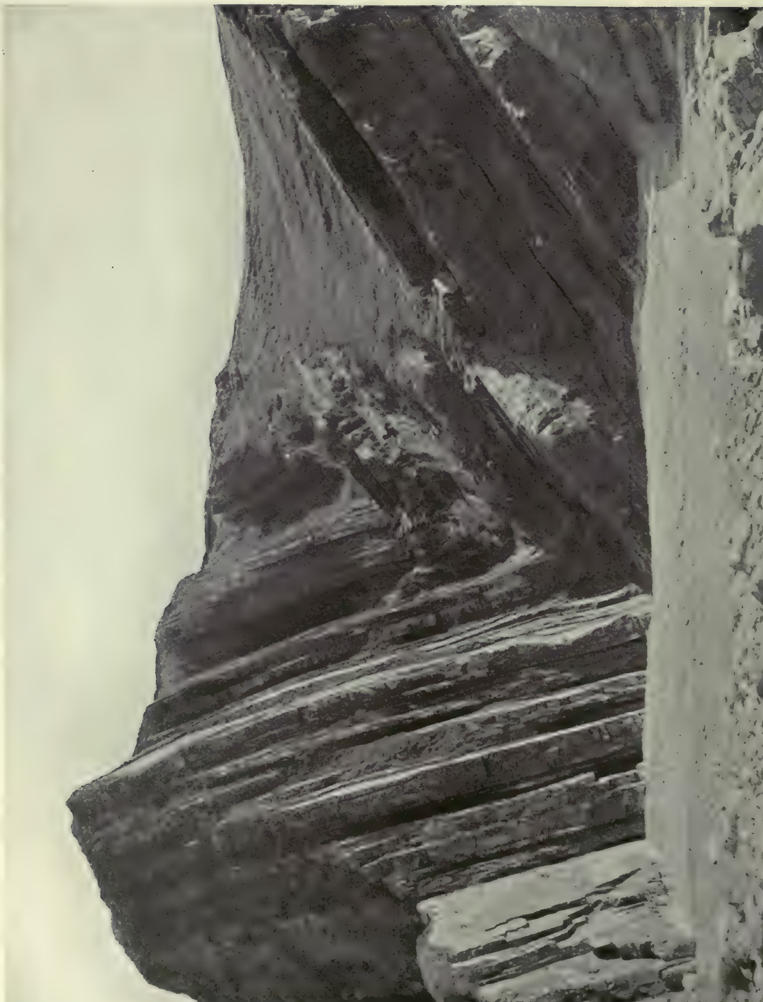
Turning to the Devonian rocks of North Devon, we find that they constitute a very varied series, as regards the characters of the beds. The following is the classification, the nature of the characteristic type of rock of each subdivision being also indicated. We will postpone until a later stage a description of the subsidiary and less important sediments, which are associated in some cases.

THE CLASSIFICATION OF THE DEVONIAN ROCKS OF NORTH DEVON.

		DISTRICT.	NATURE OF THE DOMINANT ROCK.
Upper Devonian	Pilton Beds	Mortehoe	Slates
	Baggy or *Cucullæa* Beds		Sandstones
	Pickwell Down Sandstones		Sandstones
Middle Devonian	Morte Slates		Slates
	Ilfracombe Beds	Ilfracombe	Slates
Lower Devonian	Hangman Grits		Sandstones
	Lynton Beds	Lynton	Slates
	Foreland Grits		Sandstones

This is the apparent sequence, but it is still a disputed point whether it is the real sequence (see pp. 69 and 76). These beds are distinguished from one another, not only by their lithological characters, but by the fossils which they contain, though a few of the subdivisions are practically unfossiliferous.

Plate II



A synclinal fold to the North of Bude (Hartland District).

[*To face p.* 7

The Lower Carboniferous Series of the Boscastle District consists essentially of black shales, with abundant veins of quartz.

The Upper Carboniferous rocks are alternating beds of sandstone and shale. Sometimes in one locality thick beds of shales predominate, in another, thick beds of sandstones with thin shales occur, or, in a third, we find beds of shale and sandstone, of nearly equal thickness, alternating regularly.

Although, as we have pointed out above, the general form of the whole area is that of a simple fold, or basin-shaped trough, yet the detailed structure is everywhere exceedingly complicated and difficult to follow. In fact, Devonshire and Cornwall form geologically one of the most complex regions in the whole of Britain, so far as the detailed structure is concerned. To understand how this has come about, we must go back to the time when the Lower Devonian rocks were being laid down, and endeavour to follow the subsequent sequence of events in somewhat greater detail.

The story commences with the beginning of the Devonian period, when the whole of this region was submerged beneath the Devonian sea. The muds and sands deposited on the floor of this ocean gave rise, at a later period, to the sandstones and slates of the Devonian series.

The whole of Devonshire and Cornwall probably continued depressed below sea-level during

the succeeding periods of the Lower and Upper Carboniferous, and, during these epochs, considerable thicknesses of sands and muds were deposited, which now form the sandstones and shales of the Carboniferous series. Both the Devonian and Carboniferous sediments, like those forming on the floor of the Atlantic to-day, were originally deposited in horizontal or gently inclined layers.

At length, however, towards the close of the Carboniferous period, deposition ceased, and, as the result of movements of the earth's crust, the whole region was elevated and became dry land. But the earth movements of that period were very far from being of a gentle nature. Not only was the whole district raised, but it was folded or bent into a basin-shaped structure (Fig. 1), bounded on the North and South by dome-shaped arches, which the geologist terms *anticlines*.

Devon and Cornwall continued as dry land for a long period ; in fact, as we shall see shortly, it is doubtful if this area has ever been submerged beneath the sea since Carboniferous times. The land, now exposed to all the weathering forces of nature, became denuded. Under the action of running water, rain and frost, large quantities of rock have been removed from the land and restored to the sea by streams and rivers. But this process has been at work unevenly and unequally. The exposed and elevated ground of the crests of the

Plate III

Tut's Hole, a sharp anticlinal fold in Cockington Head, near Bideford (Clovelly District).

[*To face p.* 8

folds in the North and the South (Fig. 1) were more rapidly denuded than the low-lying ground in the centre, which was naturally protected, just as to-day denudation is more rapid in the mountains than in the plains. Eventually the two great domes in the North and South, as well as part of the beds forming the central portion of the trough, were completely worn away, and submerged beneath the waters of the Bristol Channel, the Atlantic and the English Channel.

Further, the western portion of the district, then very much larger than to-day, stretched out to the West for an unknown distance beyond Lundy, and much of this area has now completely disappeared beneath the sea. For, not only has aërial denudation been at work, but the western and southern boundaries of the district have been attacked by the sea and eroded away.

By the time the Triassic period was reached, the whole of Devon and Cornwall had been greatly denuded. During this period a considerable thickness of Triassic rocks accumulated, probably under desert conditions, over the eroded surface of the Carboniferous sediments, especially in the eastern portion of the district. These, in their turn, have since been largely removed by denudation, especially in the West of Devonshire and Cornwall. A few outliers, such as that at Peppercombe, remain to tell the tale, though in the East the

Carboniferous rocks are still overlain with a considerable thickness of Triassic beds, and the eastern boundary of the Carboniferous is as yet unproved.

Such is, briefly, the general geological history of the district. It is necessary, however, to add some further remarks on the effects of the earth movements in late Carboniferous times upon the rocks themselves, if we are to understand the extraordinary cliff sections exhibited by this coastline. Although their chief effect, as we have seen, was the initiation of a large, shallow syncline, yet their actual influence on the rocks themselves was, in detail, very marked and complex. In other words, while the general geological structure of Devon and North Cornwall is quite simple, yet the detailed structure of the rocks is as complicated, and as difficult to unravel, as any met with in the British Islands, except the celebrated Highland complex in Scotland, and the sequence in South Cornwall.

The effects produced by the movements of the earth's crust and its contraction were due to lateral pressures, or *thrusts*, as they are termed by geologists. We know that if we press on a thick cloth covering a table, by placing the hands at two opposite edges of the table and moving them inwards towards its centre, the cloth will become wrinkled into a series of parallel ridges or folds, with grooves between them. If we carry this

Plate IV

Contorted sandstones and shales at Millook Mouth (Boscastle District).

[*To face p.* 10

process to its extreme limit, we find that the folds are pushed one over another. Exactly comparable effects were produced on the Devonian and Carboniferous rocks of Devon and Cornwall by the opposite lateral forces or *thrusts* of the late Carboniferous earth movements. The result has been that the sandstones, shales and limestones have been thrown into folds, or as the geologist terms them, *anticlines* and *synclines*. The folds may be simple,

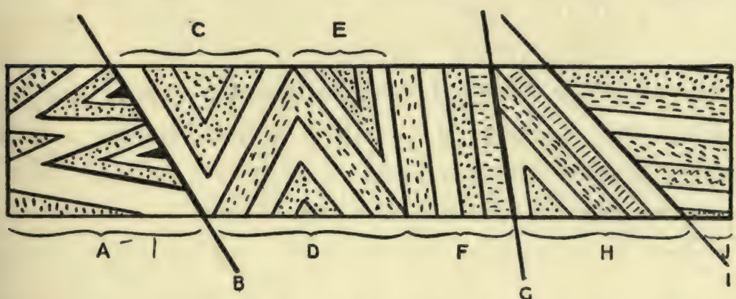


FIG. 2.—Diagrammatic view of the Carboniferous rocks of North Devon, as seen in a cliff section. A, contortions; B, G, I, faults; C, E, synclines; D, H, anticlines; F, beds tilted vertically; J, beds with low dip.

rounded anticlines and shallow synclines, such as those figured on Plates I and II. Or they may be sharp and angular (Plates III and XLVIII). In other cases the anticlines are unsymmetrical, and have an oblique and not vertical axis (Plates XXVI and XXVIII). Or again, we may find fold piled upon fold, giving complicated zigzag curves known as contorted rocks or *contortions*. Sometimes these curves are unbroken and continuous, as is seen on

Plate IV; in other cases, the curves are broken, discontinuous and faulted (Plate XL and Text-fig. 2). Such rocks are highly disturbed, and their present folded condition is in marked contrast to their original horizontal or gently inclined direction. A study of their newer and induced forms will give us some idea of the enormous nature of the forces at work in late Carboniferous times, when the rocks were literally squeezed, broken and contorted, like putty in the hands of a giant. In this lies one of the most interesting of the geological features presented by these coasts, and it may be doubted whether any other shore-line in Britain furnishes as many, and as perfect examples of folded and contorted rocks as that of Devon and Cornwall.

Not only did these earth movements induce great changes in the disposition of the beds, but, in regard to some lithological types, especially the shales or hardened, stratified muds, new features and new physical characters were also brought into existence. While the sandstones and limestones have usually remained little altered, the shales, in some regions of Devon, have become changed into *slates*. In the case of slates, the splitting planes are not the original bedding planes. As the result of pressure the latter have been sealed up, and new lines of weakness or "cleavage," along which the rock now tends to split, have been initiated.

Typical Hog's-back Cliffs at Glenthorne, on the borders of Devon and Somerset, looking East (Lynton District).

[*To face p.* 12

THE SEA CLIFFS.

The coast-line of Devon and North Cornwall is bounded by an almost continuous series of sea cliffs, from Porlock in Somerset to Boscastle in Cornwall. Only a very few small gaps occur at Woolacombe Sands, and Braunton Burrows, (North of the estuary of the Torridge and Taw), and at Bude and Widemouth in North Cornwall. The highest point, actually on the coast, is the Great Hangman, 1,044 feet, near Combe Martin, while the average height of the cliffs lies somewhere between 300 and 500 feet. The most elevated cliffs occur in the Lynton and Ilfracombe and Hartland Districts, and the lowest in the Mortehoe District.

The statement that the scenery of a coast-line, such as that of Devon, depends on the nature of the cliffs may appear pointless and obvious, but there is more truth in this remark than any one would imagine, who has not examined the cliffs of the whole of this region. There are, as a matter of fact, two distinct types of cliff to be met with in Devon and Cornwall, and, unless this fact is clearly grasped at the outset of any study of this coast, considerable difficulty may arise, when one attempts to understand the geological features of the shore-lines. The two forms of cliff may occasionally merge one into the other, but for the most part they are quite distinct (Plates V and VI).

These two types of cliff we may term the Hog's-back and the Flat-topped cliff. The latter is a very familiar type in England, and is characterised by a more or less elevated, vertical, or nearly vertical, sea escarpment, the top of the cliff being flat, or sloping very gently towards the sea (Fig. 3). The Hog's-back cliff is quite distinct (Fig. 4). In this case the land falls rapidly from a considerable distance inland, and thus a long and very steep slope is initiated, of which only the lower portion is undercut by the sea. A comparison of Figs. 3

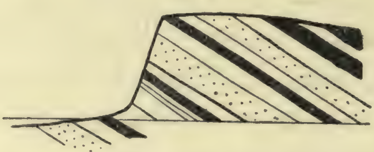


FIG. 3.—Vertical section of a Flat-topped cliff at Hartland Quay. (Scale 6 inches = 1 mile.)

and 4, which are drawn practically on the same scale from actual instances in Devon, illustrates the essential differences between the two types. In the one case practically the whole cliff is a sea escarpment, in the latter only the lower portion is sea-eroded, the rest being a surface which has originated under aërial denudation.

Nearly the whole of the cliff-line of the first three districts, those of Lynton, Ilfracombe and Mortehoe, is of the Hog's-back type. The best and most elevated examples occur between Heddon's Mouth and Combe Martin, and between Lynton

and Porlock. The seaward slope here is often so steep that it is almost impossible to remain upright on it. In the Mortehoe region the cliffs are much lower, though still of the same type. On the other hand, in the last three districts of Clovelly, Hartland and Boscastle, Flat-topped cliffs for the most part prevail, though occasionally short stretches of the Hog's-back variety may be encountered, as at the Hobby Walk at Clovelly,

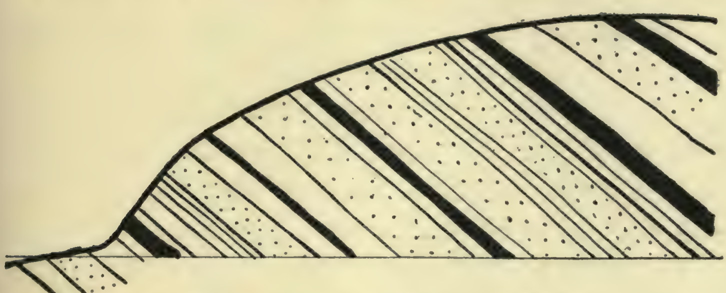


FIG. 4.—Vertical section of a Hog's-back cliff at Trentishoe Down. (Scale 6 inches = 1 mile.)

and on that part of the coast, North of Boscastle, which consists of Lower Carboniferous rocks.

The nature of the cliff-line, whether of the Flat-topped or Hog's-back type, has naturally a profound influence on the type of scenery, and, as we shall see later, on the existence of coastal waterfalls. Where the Hog's-back cliffs are very high, as in the neighbourhood of the Great and Little Hangman, the sea cuts fine escarpments, which show the characters of the rocks very

clearly. However, little or nothing of the marine denudation near their base can be seen from their summits, owing to the long curve of the slope. Such cliffs are best examined from a boat, for it is as a rule quite impossible to descend them, if paths have not been made leading to the beach. Where the cliffs are less elevated, the sea rarely cuts an escarpment of more than forty or fifty feet in height. Even this is usually of an inclined nature, and thus the section becomes easily obscured by rain-wash, or by vegetation. The sections of Hog's-back cliffs are hence less striking in extent, and more difficult to study than those of the Flat-topped variety, from the summits of which one can usually obtain an excellent view of the rocks, cut more or less vertically by the sea.

To account for the origin of the Flat-topped cliffs presents no difficulty. They are the product of sea erosion on an elevated, flat or gently sloping tableland.

But when we attempt to explain the evolution of the Hog's-back type, matters are much more difficult, and it is quite probable that at the present time we do not fully understand how such cliffs originated. The long seaward slope does certainly not depend on the nature of the rock. There is no change in the type of cliff as we pass from those East of the Foreland (Foreland Grits) to those at Woody Bay (Lynton Slates below and

Plate VI

Typical Flat-topped Cliffs, showing folded rocks, at Hartland Quay, looking North (Hartland District).

[*To face p.* 16

Hangman Grits above), or again to those at Trentishoe (Hangman Grits). The elevation of the watershed, which is being attacked by the sea, is not alone responsible for the existence of the Hog's-back type of cliff. There is, on the other hand, no doubt that the long seaward slopes are the product of aërial, and not marine, denudation. The Devonian rocks of North Devon appear to have been weathered differently from those of Carboniferous age in the central portion of the area, and since it is difficult to imagine that this result is, in the main, due to the differences in the lithological characters of the rocks, the fact remains unexplained. We find, however, that the characteristic features of the Hog's-back cliffs are not confined to the coast. The country inland is weathered in exactly the same fashion, and, in the long sloping hills and deep valleys of Exmoor Forest, for instance, we may study escarpments closely similar to those met with on the coast. It would therefore seem that the explanation of the present topographical features, both seaward and inland, must be looked for in a restoration of the past physiognomy of this county. The area occupied by the Carboniferous rocks no doubt formerly presented an entirely dissimilar aspect to the Devonian country and was therefore denuded in a different manner. It is thus to the past, rather than to the present, that we must look for the explanation of the origin of

the dissimilar sea cliffs presented by the Devonshire coast-line, and, as we shall see later, this is equally true when we seek to explain the present outlines of the coast itself.

THE COASTAL WATERFALLS.

One of the special features of this coast-line, which is of great geological interest, is the fine series of coastal waterfalls. By this term we imply waterfalls formed by streams in their passage over the sea-cut cliffs to the beach. Several of these coastal falls are of considerable height, and form striking landmarks on the coast. Their features, however, are so varied that no two of them are exactly alike in all respects. They show all stages in the evolution of a waterfall, from its birth to its senile period of old age and decay.

The streams of Devonshire are known locally as "waters," and their seaward terminations as "mouths," *e.g.* Strawberry Water and Speke's Mill Mouth. We shall also adopt these terms here.

It is sad to find that, owing to the rapid growth of the many seaside resorts along this coast, the features of geological interest presented by the seaward terminations of some of the streams have been obliterated in several cases, and the streams themselves frequently diverted or drained before reaching the sea. At Ilfracombe, Hele, Clovelly, Lee Mouth (West of Lynton), Buck's Mills, and within

the last few years at Mortehoe, among other cases, the mouths of the streams have been altered, almost beyond recognition, and, in some instances, the natural coastal waterfalls which once existed have been obliterated. No doubt it will not be many years before others will have to be added to the list.

These coastal falls will be found described in their order of occurrence along the coast, in the first six chapters, and two chapters will be specially devoted to their consideration in Part II of this volume. We may, however, briefly consider here the drainage of the whole area, in so far as it bears upon the study of these waterfalls (Map No. 1).

In the northern portion of Devon, the main drainage is the plexus of the Torridge and the Taw, which unite below Barnstaple, and flow into Bideford Bay, a few miles to the West of that town. In the western portion of Devon and North Cornwall, the Tamar and its tributaries form the main system of drainage. It is not, however, the rivers forming the principal drainage system which give rise to coastal falls. The streams which end on the coast as waterfalls all belong to a secondary or minor system of drainage (Map No. 1). Between the two systems, there is a watershed varying in height from 100–1,700 feet, with an average elevation of about 500 feet. The secondary drainage lies on the seaward side of this watershed.

The condition of affairs met with in Devon may be best described as an instance of the near advance and attack of the sea upon an elevated watershed. Between the watershed and the Bristol Channel or the Atlantic, a number of short streams, usually of small size and with few or no tributaries, drain the land towards the sea. It is these streams which in some, but not in all, cases form the coastal falls, with which we are here concerned. The sketch map opposite p. 164 (Map No. 1) indicates the drainage of the whole area, both primary and secondary, and its relation to the watershed. All the permanent streams,[1] between Porlock in Somerset and Boscastle in Cornwall, are numbered from 1 to 77, beginning in the North and East of the district. Many of them do not appear to possess names, nor are they named on the 6-inch Ordnance maps. In such cases, whenever it has been found necessary to speak of them individually, we have called them after the nearest or most important farm or hamlet. On the other hand, wherever a local name exists it has of course been adopted here.

From Map No. 1 it will be seen that in the greater part of the district the relation of the drainage to the watershed is quite simple. But in

[1] Only those streams which usually flow all the year round, or which but rarely run completely dry in summer, are here indicated.

North-east Devon, between Porlock and Combe Martin, as will be seen from the map, a secondary watershed exists, which there somewhat complicates matters. The main watershed of Exmoor Forest gives rise to the Exe and its tributaries, which flow to the southward. In the North, however, the country is drained by three streams, arising from the same watershed and flowing into the Bristol Channel, namely the East and West Lyn, Heddon's Water and the Umber (Nos. 15, 19 and 26). But in addition to these rivers there are also a number of small streams flowing to the Bristol Channel, which arise from a minor watershed close to the coast. This watershed stretches from the Little and Great Hangman to Porlock, and includes Holdstone Down, Martinhoe Beacon, Countisbury Down and the Culbone Hills. Some of the streams arising from this watershed form coastal waterfalls, just as is the case with those arising on the Atlantic side of the main watershed further South.

HINTS ON HOW TO EXAMINE THE COAST-LINE.

Before we pass to a detailed account of the scenery of this coast, it may be useful to discuss the best means of making a close geological inspection of the cliffs. It is possible nowadays to drive over well-made roads, round nearly the whole

of this coast, usually within sight of the sea, and sometimes quite near its margin. It is equally safe to add that, by so doing, little or nothing of the geology can be seen. There is also an almost continuous series of cliff paths from Porlock to Boscastle, which are already well known to many as favourable ground for walking tours. By following such tracks, with occasional digressions, it is possible to see a great deal of the geology of this splendid series of cliffs. Sometimes, indeed, this is the only possible course. But to those who are interested and active no better advice can be given than to combine with the cliff walks the more difficult and much more laborious task of progressing along the beach. The visitor to these coasts should not be content to see the coast sections and the waterfalls from the cliff top, but should insist, wherever it is possible, on inspecting them from the beach also. With a little determination at hand, it is but rarely impracticable to reach the beach and the foot of a fall. Geology from a cliff-top is like geology from an arm-chair, a thing to be avoided.

The majority of the more interesting geological structures described in the present volume can be inspected from the shore without any special exertion or difficulty. At the same time it is true that in many districts, in order to make any progress along the beach, energy, strength

and determination are necessary, and a small element of danger is not altogether absent. The latter is never, however, serious, if proper precautions are taken. Rock climbers, and those fond of scrambling in unfrequented places, will find in the beaches of the roughest portions of this coast a new paradise, which is certain to meet with their approval. The "going" is of the roughest description, and progress is slow, a uniform rate of about a mile an hour being reckoned as the average.

But to those who are attracted by cliff scenery it is not as a mere form of exercise that such beach expeditions are necessary. No words can convey the wildness and grandeur of these cliffs, as seen from the shore, even in some of the least interesting portions of the coast, while in the Hartland District the scenes baffle description completely. To the geologist, the magnificent sights presented by these cliffs are hardly more interesting than the extraordinary spectacles which the rocks themselves present, torn apart by the sea, dissected this way or that, so that the very structure of the district is exposed to the light of day. It is but rarely that any of these things can be favourably studied from the cliff-top. Further, if we wish to inquire exactly how the sea works at the coast, and what happens under a great variety of circumstances when the cliffs are being eaten into by the sea, access to the shore is obviously necessary.

Since it is often imperative to explore the beach at the foot of the cliffs, if we are to see some of the interesting geological sights in the district, we may perhaps be pardoned if we digress somewhat further to point out how the chief difficulties which will be met with may be overcome, and any risk of danger averted. There are three golden rules to be observed. First of all, study the length of beach to be traversed on a large-scale map, and also, if possible, from the cliff-top before the attempt is made. Secondly, make sure of the tides beforehand ; and, thirdly, never venture alone.

There are, of course, many stretches of beach which present no difficulties, and which are suitable for a stroll, if of a somewhat rough nature. But what we have to say here applies to the rougher portions of the coast. Plan out on a large-scale map exactly what you propose to attempt, your advance and your retreat. The best maps are those of the 6-inch Ordnance Survey,[1] which are inexpensive, costing one shilling a sheet.

These maps are crowded with data of use to the beach scrambler, though a little practice is

[1] These "County" maps are stocked by Edward Stanford, 12–14 Long Acre, London, W.C., from whom they can be obtained at short notice. The index numbers of the sheets, as also those of the 1-inch ordnance, "General" maps, relating to the coast-line described here, are given in Chapters I–VI, under the districts to which they refer.

necessary to enable one to read off all the information that such maps can convey.

Having decided, either from the map or by previous inspection, that the shore-line can be reached at a certain place, the next point to be determined is whether, when you have progressed up or down the coast a certain distance, you will return the same way, or regain the cliffs at another point. The only difficulty with the tides is whether you have time to do all you propose. It is essential to have a fairly definite idea before starting of how you will retreat from the shore. If you intend to regain the cliff at a place which, when you eventually reach it, proves to be impracticable, then the tides may become a matter for serious consideration. In any case, care should be taken beforehand to ascertain the time of high-water as exactly as possible, and also the height of the tide. This information can usually be obtained from the local newspapers, or the coast-guard. It is only under circumstances of gross carelessness in this respect, of lack of forethought as to the line of retreat, or in cases of accident, that the tides present any element of danger. At the worst, if the tide is going to catch you, you ought to be fully aware of the fact at least two hours before high-water. If, having suppressed the instinct to fight against circumstances, you spend such time as remains in looking about for a suitable shelf in the cliffs, instead of

trying the impossible task of returning the way you came, no difficulty will be found in securing a safe, if uncomfortable, refuge. The author after many years' experience of shore scrambling in Devonshire, has never yet had the misfortune to be caught by the tide, so the danger in this respect is not great.

For explorations along the shore, the presence of at least one, or better still two, companions is highly desirable. The author has never heard of any accidents, and the worst thing which has ever happened to any member of his parties has been an involuntary bath in a pool of sea water, as the result of a slip. But sprained ankles are conceivable at any time, and if the unfortunate member has the help of friends at hand, he will be able to reach some position of safety without much difficulty.

The work of "beach crawling," as it may be called, has something in common with rock-climbing, but it is much less dangerous, for the rocks are less treacherous, and in the case of a slip one can only fall a few feet. The art consists in moving rapidly from one boulder, of from five to twelve feet in height, to another of similar height, and for this purpose long alpenstocks are found to be very useful.

It would indeed be a proud accomplishment to have traversed the whole of the shore-line from Porlock to Boscastle. Whoever manages to accom-

plish this feat in the future will have seen wonders in the way of cliff scenery, and can also boast of a remarkable record. After many expeditions with experts in the art of "beach crawling," there are still several miles which the author has been unable to traverse by means of the beach. One hesitates to say that the task is impossible, for at spring tides one can sometimes accomplish seemingly extraordinary feats in the way of rounding obstinate points. Certainly it will not be perfected without special studies of the difficulties and opportunities, studies as serious, perhaps, as those which were necessary when, in former days, some untrodden Alpine peak was to be attacked.

PART I

THE COAST SCENERY OF THE SIX DISTRICTS IN SOMERSET, NORTH AND WEST DEVON, AND NORTH-WEST CORNWALL

CHAPTER I

DISTRICT I.—THE LYNTON DISTRICT

Our first district extends from Porlock in Somerset to Woody Bay in North Devon, some distance west of Lynton. The cliff scenery throughout is of the Hog's-back type (p. 14). The coast between Porlock and the Foreland is perhaps of less interest, from a geological standpoint, than any other stretch of cliff-line in the whole area, but this is compensated for by the proximity of Exmoor. On the other hand, the cliffs West of the Foreland, including the celebrated scenery of the neighbourhood of Lynton and Lynmouth, are extremely interesting and picturesque.

The geological formations represented in the district belong to the Lower Devonian. From Porlock to the west side of the Foreland, the beds consist of sandstones, known as the Foreland Grits. From the Foreland to Woody Bay, the Lynton beds prevail. These consist chiefly of slates, with some limestone, sandstone and shale beds.

Headquarters.—Lynton or Lynmouth are fairly central, while Porlock and Woody Bay are at the opposite extremes of the

district. From the point of view of attractiveness the order Lynton, Woody Bay and Porlock will be generally accepted, the first-named being the most beautiful resort. Porlock, which is chiefly of interest from its proximity to the eastern end of Exmoor, is reached by railway from Taunton (G. W. R.) to Minehead, and thence by coaches or buses which connect with the principal trains. Porlock is six miles from Minehead.

Lynton, and Lynmouth, are reached from London and Exeter, by L. and S. W. R. to Barnstaple Town ; or from London, Bristol and Taunton to the same station in Barnstaple (which possesses three stations—Barnstaple Junction, Barnstaple Town, and Barnstaple G. W. R.) by G. W. R., thence by a narrow-gauge railway to Lynton. The station stands at a considerable distance above Lynton, and still further from Lynmouth, which lies at the foot of the cliffs on which Lynton is perched.

Woody Bay is reached by the same line, the station Woody Bay being the last before Lynton, on the Barnstaple to Lynton narrow-gauge line. From the station to the coast is a drive of two miles, and more to the hotels.

Directions.—Under this heading it is proposed to indicate, in the case of each district, the best means of reaching the cliffs and the shore-line, in order to study their geology. From Porlock to the Foreland Point, Exmoor is being cut into by the sea, and the seaward slope of the Hog's-back cliffs may be traversed by several paths, which are open to the public. From Porlock to the Foreland the coast-line is scarcely indented, and, as far as Glenthorne, the county boundary, the cliffs are heavily wooded with oak. West of Glenthorne they are for the most part bare, though the combes are densely wooded. From the main cliff path from Porlock, via Culbone and Glenthorne, to Countisbury (about twelve miles), the shore may be reached by several paths without difficulty, especially between Silcombe and Twitching Combes, at Embelle Wood Beach, at Wheatham Combe, at Glenthorne, at the Giant's Rib, at Desolation Point and Countisbury Cove. The shore-line, however, presents few details of geological interest.

The cliff paths are but little used, and it is sometimes difficult

even with the aid of a 6-inch map to hit off the right track, or, in the cases of the old ways to the beach, to trace the path at all. The way from Culbone onwards, going West, is not easy to find. When coming East from the direction of Glenthorne to Porlock, cross Culbone Churchyard and take the public path to the left along the wall of the churchyard. Plenty of time should be allowed for walks along the slopes of these Hog's-back cliffs, on account of the difficulty of keeping the track.

The Foreland Point can be studied from the shore by taking the path on the east side down to Countisbury Cove, or by proceeding along the shore eastward from Lynmouth, or by means of the path down to Sillery Sands, or by boat from Lynmouth. It is doubtful, however, whether it can be doubled on foot at any state of the tide.

The shore to the West of Lynmouth can be explored from the mouth of the river Lyn, for some little distance, but the going is rough. The next place further West where the shore can be reached is Wringcliff Bay, just beyond the Castle Rock.

To see the celebrated Valley of Rocks, however, we take the cliff path (known as the North Walk) or the road to Lee Abbey from Lynton. The distance to Woody Bay, via Lee Mouth, is three and a half miles. Beyond the Valley of Rocks, typical Hog's-back cliffs continue to Woody Bay. The first part including Duty Point is private property, and the public is restricted to the carriage road past Lee Abbey to Lee Mouth, at some distance from the cliffs.

A road leads to the shore at Lee Mouth, and the west side of Duty Point and the east side of Crock Point may be explored at suitable states of the tide.

Between Lee Mouth and Woody Bay, a road and several paths traverse the beautifully-wooded Hog's-back cliffs, but there is no means of reaching the shore until the path from the Woody Bay hotels is reached. From the shore, near the ruined limekilns at the old pier, the coast may be explored some distance to the East towards Crock Point, but to the West progress along the rough shore is more limited.

Maps.—The numbers of the Ordnance Survey Maps, relating to the coast-line of this district, are :—

One-inch scale : Sheets 278 (Porlock), 277 (Lynton).

Six-inch scale : Somerset—XXXIV. N.W. (Porlock), XXIII. N.E. (Ashley Combe *only*), XXII. S.E. (Culbone), XXII. S.W. + *Devon* Sheet III. (Glenthorne). *Devon*—III. N.E. + S.E. (Glenthorne, partly overlaps the last map), III. N.W. + S.W. (Foreland, Lynton), II. S.E. (Valley of Rocks to Woody Bay).

THE PORLOCK SECTION.

The first of the three sections, into which the Lynton District may be subdivided, begins at Porlock, in Somerset, and ends at the Foreland in Devon. The broad seaward termination of the Vale of Porlock is interesting from the fact that, before the Norman Conquest, Porlock itself was washed by the sea, whereas it is now distant about a mile and a half from the waters of the Bristol Channel. The lower portion of the Vale has been silted up by river sediments, which were probably deposited behind a bar of shingle, stretching across from Hurlestone to Gore Points, and the land thus reclaimed from the sea is now largely cultivated. The cliffs bordering the western side of the road from Porlock to Porlock Weir, were once sea-cliffs.

A submerged forest exists in Porlock Bay, between Hurlestone and Gore Points, which is sometimes laid bare near low-water mark at very low tides, when the coast has been swept clear of shingle after a storm. Numerous stumps of trees,

said to be chiefly oaks (with black wood) and alders (with red wood), are studded about, some being rooted *in situ*, and surrounded by deposits of mud. Further inland, the forest beds are hidden under the shingle beach. Such submerged forests are common all round the coasts of England, and afford evidence of their slow depression within comparatively recent periods.

To the West of Porlock, the great table-land of Exmoor commences, which is being cut into by the sea. The Hog's-back cliffs, however, between Porlock and Countisbury (Lynton) are not very interesting geologically. The rocks belong to the Foreland Grit series throughout, and are unfossiliferous, save for some obscure, stem-like impressions, vaguely termed Fucoids, which were discovered at Porlock many years ago. The beds consist of hard, red, or purplish, or grey, fine-grained sandstones, or flaggy grits, forming thick beds, with occasional partings of hard compact shales, and pebble beds. The red sandstones recall the Old Red Sandstone type of Devonian in South Wales.

The cliffs begin to rise near Porlock, and reach a height of over 1,300 feet in Culbone Hill, of 1,062 feet at County Gate, whence they continue at about the same level as far as Countisbury. From the crest of the cliff, the distance to the sea in a direct line is, as a rule, between three-quarters

of a mile and a mile. In this space the land falls sharply from 1,300 feet or 1,000 feet to sea-level, and thus the steep, seaward slope of a typical Hog's-back cliff is initiated, such as that shown in the photograph on Plate V.

As one would expect, when the sheltered position of this coast-line is remembered, very little sea denudation is going on at the base of the cliffs. The protected waters of the Bristol Channel, so far removed from the open sea, have naturally little power of erosion, even in times of storm. In addition, the base of the cliff is usually protected by a considerable accumulation of pebbles, and in some places is scarcely undercut by the sea. Thus good exposures of the rocks are not so numerous as in other districts, and further the base of these cliffs is, in summer-time, largely obscured by vegetation.

An examination of the drainage of this long cliff-line is, however, of interest (Map No. 1). Between Porlock and the Foreland, there are some fourteen small and short streams, rising near the summit of the Hog's-back cliff and traversing as many combes to the sea. A few of these streams even possess tributaries. All of them have cut deeply into their valleys, so much so in fact that many of them are at base-level at their mouths, or lose themselves in the landslipped foot of the cliff, or in the pebble ridge, and thus their seaward terminations may be difficult to locate. Others, again, are

Plate VII

FIG. 1.—Hanging Water Fall at Woody Bay (Lynton Slates).

FIG. 2.—Coscombe Water Fall, Glenthorne (Foreland Grits).

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sometimes apt to dry up completely in summer. A few do, however, end in waterfalls over the undercut lower portions of the cliff.

THE WATERFALLS.

The waterfalls which occur on the Hog's-back cliffs are rarely so high or so imposing as those to be found in districts where the Flat-topped type of cliff prevails, since only the lower portion of the cliff is being worked by the sea (Fig. 4). The fall of Coscombe Water (Plate VII, Fig. 2, No. 8 on Map No. 1) at Glenthorne, the county boundary, is quite typical of a waterfall over a Hog's-back cliff, and bears a close resemblance to the equally typical fall at Woody Bay (p. 47) further to the West. The stream above the fall has cut down deeply into the cliff, and it terminates in a sheer fall, which is only some twelve or fourteen feet in height.

A finer fall may be studied at Desolation Point, which, however, is not very easy to reach, although a rough path traverses Wingate Combe to the shore. Wingate Water (No. 9 on Map No. 1), the next stream to the West of Coscombe Water, is formed by the union of three brooks, watering as many deep combes. These unite close to Desolation Point. Just above the fall over the sea-cut termination of the cliff, the stream divides

into two, and thus two falls occur side by side, each apparently between forty and fifty feet in height. The water passes over the seawardly inclined limb of an anticline, which is worn away unevenly, the hard beds standing out as steps, and consequently the fall consists of a succession of parallel leaps from ledge to ledge. This fall affords an excellent illustration of how a sheer waterfall may be broken up into a number of leaps by the uneven weathering of the cliff over which it passes. It is certainly worth a visit, for besides being very pretty, it is one of the finest examples of a Hog's-back cliff waterfall to be found on the whole coast.

Those who are interested in the geology of valleys should not fail to visit the great cirque of Coddow Combe and its tributaries, on the East side of the Foreland. The depth of these valleys is not less extraordinary than the steepness of their walls, which are so abrupt that no soil or vegetation covers their sides. This valley has not yet reached base-level at its seaward termination. It possesses a very small stream, now diverted to tanks which supply water for the lighthouse on the Foreland. At one time, no doubt, this stream ended in a waterfall over the sea-cut termination of the cliff, which is here nearly a hundred feet high. Nowadays, however, so little water passes seaward, beyond the tanks belonging to the lighthouse, that

the termination of this stream possesses little or no interest.

THE LYNMOUTH SECTION.

THE FORELAND.

The coast stretching from the Foreland to Lee Mouth will be here termed the Lynmouth Section of the Lynton District. The extremity of the Foreland, the point which is so prominent to the East of Lynmouth and Lynton, consists of Foreland Grits, and is really part of an old range of hills running North and South, which is now being cut into by the sea on two sides. Some of the streams draining this watershed on the eastern side, such as Coddow Water, just mentioned, still exist, but all those on the western side have long since disappeared beneath the sea. The greater portion of the long, open curve, from the Point towards Lynmouth, consists of slates of the Lynton Beds.

The junction between the Foreland Grits and the Lynton Slates occurs at the third spit of beach from the actual point, and is best examined by means of a boat from Lynmouth. It is, however, not clearly seen, as the rocks are here obscured by rain-wash and talus, and little can be made out of the relationship of the beds. The actual junction is believed to be quite near the gully marked " Great

Red," on the 6-inch Ordnance map, to the North of Upper Blackhead. The beach known as Sillery Sands, which is the nearest point where the shore can be reached from the cliff, consists of Lynton Slates which are much folded and contorted in places.

The Lynton Beds may be also examined in detail on the east side of Lynmouth Harbour, along the promenade on the west side of the little pier, and in a quarry at the commencement of the famous North Walk at Lynton. Certain types of rocks belonging to the Lynton Series may be studied in many places in the Valley of Rocks.

The Lynton Beds consist of grey slates and shales, with interbedded grits, which are often ripple-marked and false-bedded (as may be frequently observed in the Valley of Rocks). Calcareous bands may also occur, which, however, are much more abundant in the lower portion of the series near Lynton than in the higher beds further West. The total thickness of the Lynton Beds is between 1,200 and 1,500 feet.

Fossils are fairly abundant in the Lynton Beds at Lynmouth, though they are usually fragmentary, and occur chiefly as impressions or as imperfect casts. Of the Brachiopoda, *Orthis arcuata* (Phillips) is very abundant, especially at Watersmeet. The following are the chief recorded species from these beds :—

Corals—

Pachypora cervicornis (Blainv.).
Petraia pluriradalis (Phill.)

Trilobites—
Phacops latifrons (Brown).
Echinodermata—
Actinocrinus tenuistriatus Phill.
Gasteropoda—
Pleurotomaria aspera Sow.
Brachiopoda—
Athyris concentrica (v. Buch).
Chonetes hardensis (Phill.)
Spirifer hystericus ? (Schloth.).
Polyzoa—
Fenestella plebeia M'Coy.

Fish remains of a fragmentary nature have been also obtained, and quite recently fish bones, allied to those of *Pteraspis*, have been recorded.

THE LYN.

The cliffs on both sides of the mouth of the Lyn are typical of the Hog's-back type. That of the Foreland as viewed from Lynmouth pier presents an exceptionally steep-sided example.

In the Lyn, we have one of the major streams of the district, and one which has long since reached base-level at its mouth, as also has its tributary the West Lyn, which joins it only a few yards from its seaward termination. It is an open question how far the gorge of this river may be regarded as of the nature of a canyon (see p. 217). It has been much altered by human agency, and many features of interest have been obliterated or covered up by buildings.

The valley of the East Lyn, above the bridge, is very steep-sided, like nearly all the combes in Devon. It traverses an anticline, and one feature of special interest is that it enters the sea, not at right angles to the general trend of the coast-line, but at a very acute angle, and the sea is directly attacking its northern wall, which is known as the Tors. As we shall see in other cases in Devonshire which will be discussed in Chapter X, where a similar state of affairs is met with, exceptionally interesting results may be brought about by erosion of one of the lateral walls of a valley by the sea.

LYNTON.

In the cliff which separates Lynton from Lynmouth, which is about 400 feet high, several grey bands of hard, crystalline limestone occur, some of which are between twenty and forty feet in thickness.

These beds contain—

Spirifera hystericus (Schloth.).
Spirifera lævicostus (Valenc.).
Orthis arcuata Phill.
Pachypora cervicornis (Blainv.).

THE VALLEY OF ROCKS.

To the West of Lynton lies the extremely interesting Valley of Rocks, which should be examined both from the North Walk, along the

Plate VIII

The Valley of Rocks, with the Castle Rock and Rugged Jack, looking East (Lynton District).

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face of the cliff, and also from the road, which traverses the centre of the valley. The two paths meet at the western extremity of the valley.

The Valley of Rocks is a streamless valley, running for the most part parallel to the coast-line. At a point just west of Castle Rock, it turns seaward, and is there cut off abruptly by sea erosion.

The seaward wall of this valley has been greatly weathered, and reduced in height, by aërial denudation (Plate VIII). The picturesque nature of its celebrated scenery depends, not only on this fact, but also on the nature of the rocks which build up both its walls. The Lynton Beds here consist of impure soft sandstones, often much ripple-marked. Each sandstone bed is, as a rule, only one or two feet thick, and the successive beds are of nearly equal thickness. They weather easily along the numerous joints and bedding planes, which are cut out and enlarged by the action of rain, frost and wind combined. Owing to this fact, and also to the disposition of the beds, which are nearly horizontal or only slightly inclined, each bed of sandstone tends to weather out as an isolated rectangular block, and thus we find a succession of slabs piled one upon another. With the exception of the lower portion of the Castle Rock (Plate IX), this is brought about entirely by aërial, and not marine, denudation.

In many places along the walls of this valley, especially on the seaward side of the northern wall, the rocks are in an unstable condition, and the piles tend to tumble into a shapeless scree, which is far from being picturesque. A similar talus of fallen and broken fragments occurs on the landward side of the "Castle Rock" (Plate IX) near its base. But in the case of the "Castle Rock," and "Rugged Jack" on the west side of the valley and the "Devil's Cheesewring" on the east, the large piles of weathered fragments are in stable equilibrium, and form picturesque ruin-like masses, nearly equally weathered on all sides. No doubt in these cases the sandstones were somewhat harder and more resistant than the surrounding rocks, but the degree to which the weathering has been perfected also depended to some extent on the stability of the beds, which have continued sufficiently long in their original position to permit of the deep carving out of the joints and bedding planes. Castle Rock is the largest of these unbound masses of natural masonry, and, from its summit, the equilibrium of the ripple-marked blocks affords an interesting study in circumdenudation.

The tendency of hard rocks to "weather out," as the geologist terms it, and thus to rise above the general level of the district, is a very common one. Similar piles of weathered rocks occur at Morte Point, and consist of Morte Slates, but they are

Plate IX

The Castle Rock, with Duty Point in the distance, looking West, from the North Walk, Lynton.

[*To face p.* 44

small in comparison, less picturesque and less regular, and thus rarely noticed.

At the summit of the steep southern wall of the Valley of Rocks, above the "Devil's Cheesewring," the Hangman Grits, the next highest division of the Devonian, overlie the Lynton Beds. The seaward slope of the northern wall is a long Hog's-back cliff, comparatively little undercut by the sea. Thus no very prominent or interesting rock sections are to be seen from the beach, which is strewn with rectangular or nearly cubical boulders, derived from the cliff above. Two caves occur, however, beneath "Rugged Jack."

LEE MOUTH (LYNTON).

Passing over the ridge in Lee Abbey grounds, we soon find ourselves at Lee Mouth, one of two places of this name on the North coast of Devon. Duty Point is private property, and thus neither its picturesque cliffs nor beach can be explored. Lee Mouth may be regarded as the natural dividing line between the Lynmouth and Woody Bay Sections of this district.

There is a stream here, the first West of the Lyn, and no doubt at one time some kind of waterfall existed at its mouth. But its seaward termination has long since been drained, and altered beyond all recognition.

The Lynton slates may be examined at low tide

in Lee Bay. Some of the beds contain fossils which are for the most part the same as those found at Woody Bay.

THE WOODY BAY SECTION.

Immediately West of Lee Mouth, there is a break in the run of the Hog's-back cliffs, and a curious rectangular area of almost flat cliff is interpolated at Crock Point, which affords picturesque views of Duty Point to the East, and of Woody Bay to the West. The possible explanations of the origin of this cliff will be discussed in Chapter X.

The Hog's-back cliffs continue until we reach Woody Bay, which is itself a most typical example of this form of cliff, 900 feet in height. Its wooded slope is so steep that it is impossible to follow it in many places, where no path exists, and the engineering of the road down to the shore is eloquent of the steepness of its slope.

Near the top of the cliff the Hangman Grits overlie the Lynton Slates, but the latter alone occur on the beach.

Fossils are not very abundant in the Lynton Beds at Woody Bay. The more important are :—

Polyzoa—
- *Fenestrella plebeia* M'Coy.

Brachiopoda—
- *Orthis granulosa* Phill.
- *Orthis arcuata* Phill.
- *Spirifer lævicostus* Valenc.

Lamellibranchia—
Pterinea spinosa Phill.
Gasteropoda—
Pleurotomaria aspera Sow.
Bellerophon subglobatus M'Coy.
Cephalopoda—
Actinoceras devonicans Whidb.

Hanging Water, the stream flowing over the steep slope of Woody Bay, is a typical example of a brook traversing a Hog's-back cliff. It has a very short course, falling 900 feet in less than half a mile. It tumbles or cascades rapidly down the slope of the cliff, and, at its foot, ends in a fine fall, about thirty feet in height, over the sea-cut termination on to the shore (Plate VII, Fig. 1). The fall closely resembles that of Coscombe Water, Glenthorne (p. 37, Plate VII, Fig 2), and both these falls are very different in their general physiognomy from those in the districts where the Flat-topped type of cliff prevails.

CHAPTER II

DISTRICT II.—THE ILFRACOMBE DISTRICT

Our second district in North Devon extends from Woody Bay to some two miles West of Ilfracombe at Lee Bay (a place not to be confounded with that of the same name between Lynton and Woody Bay). The nature of the cliff scenery is extremely varied. Between Woody Bay and Combe Martin very elevated, typical Hog's-back cliffs prevail. Further West, the cliffs are lower, and of a more gradual slope, though still of the same type. A much indented shore-line is also found here.

The first section of the coast is the wildest and grandest. The neighbourhood of Ilfracombe, both to the East and West, has been much "civilized," and many of its geological features of interest have been spoilt, although the scenery is fine where it is not disfigured by modern buildings.

The geological formations of this district are the Hangman Grits of the Lower Devonian, and the Ilfracombe Beds of the Middle Devonian. The former consist almost entirely of sandstones, while

the latter are chiefly slates, though limestones, shales and sandstones also occur.

Headquarters.—The most convenient headquarters along this considerable stretch of coast are Hunter's Inn (or even Woody Bay), Combe Martin and Ilfracombe. Combe Martin is perhaps the most central spot, though the least picturesque as regards scenery. Hunter's Inn and Woody Bay are reached by carriage or coach from Lynton or Ilfracombe, or from Woody Bay station on the Lynton line (see p. 32). Combe Martin is reached by coach or carriage from Lynton or Ilfracombe. Ilfracombe may be reached from London by two routes: (1) the L. and S. W. Railway, via Exeter, Barnstaple Junction, and Barnstaple Town, and thence by G. W. Railway to Ilfracombe direct, or (2) the G. W. Railway, via Bristol, Taunton, Barnstaple (G. W. Rail. station) and Barnstaple Town, thence as above.

Directions.—From Woody Bay to Combe Martin Beach, Hog's-back cliffs of the highest type prevail. As far as Hunter's Inn, there is a choice of a carriage road high up on the cliffs, or of a rough path, not altogether safe on a windy day, about half-way down the slope.

The rocks of the shore-line may be examined at Heddon's Mouth (one mile from Hunter's Inn), but, in the author's experience, it is not possible to reach the beach at any other point between Woody Bay and Combe Martin, except with the aid of a boat. The crest of the Hog's-back cliff between Hunter's Inn and Combe Martin can be easily gained from the southern face at either end, and one can explore the bleak, desolate summits of Trentishoe Down (1,061 feet) Holdstone Down (1,146 feet) and Girt Down (960 feet), but the long and very abrupt, seaward slope cannot be descended for any distance towards the beach, on account of its extreme steepness. The only chance of exploring the foot of these cliffs is by sea from Lynmouth, Combe Martin, or even Ilfracombe.

The western termination of this section of the coast consists of two hills, which are being rapidly dissected by the sea, the Little

Hangman (716 feet) and, to the East, the Great Hangman (1,044 feet). Their crests are easily reached from Combe Martin, via West Challacombe.

On the West side of the Little Hangman, there is also a path down to Wild Pear Beach, which is a continuation of the road past West Challacombe farm. The important junction of the Hangman Grits and the Ilfracombe Beds is very well seen in the northern portion of this cove.

Perhaps the best way to study the magnificent cliffs between Woody Bay and Combe Martin is to choose a fine day, and take a sailing boat from Lynmouth, westward as far as Heddon's Mouth. On another occasion, a boat from Combe Martin eastward (at least as far as the fine fall at Sherrycombe) will complete the survey of this section of the coast. At low water, it is also possible to examine the rocks on either side of the little estuary at Combe Martin, with the aid of a boat.

West of Combe Martin, good views of the indented coast may be had from the road to Ilfracombe, from Watermouth (above the caves) and from Rillage Point, but at no place can the shore be gained, except by boat from Ilfracombe or Combe Martin, until we reach West Hagginton Beach near Hele. Watermouth is private property, and the public is only admitted to the landward end, where there is an interesting cave, for admission to which a fee is charged. The very remarkable Ilfracombe Slates can, however, be studied at West Hagginton Beach, Hele Beach, Broadstrand Beach (on the North-west side of Hillsborough) and at Rapparee and other coves, immediately to the East of Ilfracombe.

At Ilfracombe, and to the West of that town, the shore can be gained at Wilder's Mouth, at the Bathing Places (via the Tunnels) and by a path leading to the beach from the Torr's Walk. Further West, there is no means of access to the beach, so far as the author is aware, except by boat from Ilfracombe, until we reach Lee Mouth. The road from Ilfracombe to Lee Bay lies at some little distance from the coast.

Maps.—The Ordnance Survey Maps relating to the district are :—

One-inch Scale: Sheets No. 277 (Woody Bay to Ilfracombe) and 276 (Ilfracombe to Morte Point).

Six-inch Scale: Devon II., S.E. (Woody Bay); II., S.W. (Heddon's Mouth); I., S.E. (Combe Martin, coast only) [V., N.E., Inland portion of I., S.E.]; IA., S.E. & S.W. (Coast, Watermouth, Ilfracombe) [V., N.W. Inland portion of the last with town of Ilfracombe]; IV., N.E. (Ilfracombe to Lee Mouth).

This stretch of coast-line may be conveniently divided into two sections, the Combe Martin, stretching from Woody Bay to the village of that name, and the Ilfracombe, from Combe Martin to Lee Mouth.

THE COMBE MARTIN SECTION.

The coast-line from Woody Bay to Combe Martin, with the exception of Heddon's Mouth (from Hunter's Inn) is probably less visited than any other portion of North Devon bordering on the Bristol Channel. It is for the most part a wild and desolate moorland, ending towards the sea in extremely elevated, and abrupt Hog's-back cliffs. There is probably no region in the whole of Devon where this type of cliff can be studied to better advantage.

HOLLOW BROOK.

Between Woody Bay and Heddon's Mouth, there is only one coastal feature of interest, and that is the stream known as Hollow Brook. This ends in the highest and finest waterfall to be found

along the whole stretch of the Hog's-back cliffs of North Devon. It can only be seen by taking a boat down the coast from Lynmouth.

Hollow Brook rises at Martinhoe village, at the summit of the Hog's-back cliff, at an elevation of about 800 feet. It falls to sea-level in a distance of about 1,000 yards, almost in a straight line. Its average gradient is thus more than 1 in 4. It is a stream of medium size, without tributaries. Its highest portion, between Martinhoe and the main road, is the least steep. Between the road and the cliff-path, its course is more abrupt and it forms cascades several feet in height. Below the path it disappears over the cliff, and ends in a very fine fall on to the beach, exceeding 200 feet in length. This fall, when examined by means of a boat, is found to be situated in a little narrow gully, cut by the sea. The waterfall does not lie at the head of the gully, but the water comes over its southern wall near its inland termination. The water flows in the opposite direction to the dip of the beds (*counterdip*). The upper part of the fall consists of two converging leaps, uniting below in a third leap. Although this fall has not been measured, it must be nearly 200 feet in height. It ends on the boulder-choked floor of the gully, through which it makes its way to the sea.

HEDDON'S MOUTH.

The coast between Hollow Brook and Heddon's Mouth, as seen from a boat, is interesting as showing the Hangman Grits of the Middle Devonian coming in over the Lynton Beds, high up in the cliffs. This may be also seen in the valley of the Heddon.

The Heddon is a large stream, now at base-level at its mouth. As we pass along the last mile of this river, from Hunter's Inn to Heddon's Mouth, we notice the extraordinarily steep nature of the walls of the valley on both sides. So abrupt is the slope, that the sides of the valley are almost bare of soil and vegetation. The walls are 700 feet in height, and the gradient in places is somewhere about 7 in 10. Such a valley offers us an excellent idea of the former erosive power of its river. Its V-shaped form is, however, partly due to the tendency of the debris, derived from the weathered rocks of its walls, to slip downwards, or to be washed down by rain. The geologist terms this phenomenon *soil-slip* or *soil-creep.*

TRENTISHOE DOWN.

By climbing the steep wall of the Heddon, or preferably by taking the road from Hunter's Inn to Trentishoe, we find ourselves on the summit of a vast moorland, which stretches through Trentishoe

and Holdstone Downs, as far as Sherrycombe, Girt Down and the Great Hangman. The Hog's-back cliffs here are between 1,000 and 1,100 feet in height, and the seaward face is so steep that it is impossible to descend it. Below, they are undercut by the sea for several hundred feet. Towards Trentishoe, the upper portion of the slope is less abrupt and the land is cultivated, but from Trentishoe Burrows to Sherrycombe, the Downs consist of bare moorland, with little vegetation. Standing on the summit of these cliffs and looking seaward, one seems to gaze into an empty space, so steep is the slope, beyond which is the sea, some distance away.

The rocks forming the cliffs are the Hangman Grits. These are grey or red, spotted, gritty sandstones, with a few associated beds of shale. They are almost entirely unfossiliferous, though it is recorded that in the highest beds at Challacombe, Netherton, etc., near Combe Martin, casts of a *Myalina* and a *Natica* have been found. The former are also said to occur in the weathered slabs on the Little Hangman and on Holdstone Down, and the latter on the southern flank of Sherrycombe.

Seaward the coast is little indented. In this respect it presents a striking contrast to that between Combe Martin and Ilfracombe. Several caves are, however, to be seen, worn by marine erosion in the undercut portion of the cliff.

Between the Heddon and Sherrycombe, there are a few small streams draining the cliff seaward, but, in summer, they usually contain very little water. Two of these occur at Neck Wood (Nos. 20 and 21 on Map No. 1) close together, the one on the East being the larger. When examined from the sea, in September 1910, the easternmost was found to be only a small trickle down the face of a broken undercut cliff, and that to the West was dry. Further along the coast, towards Combe Martin, there is another small stream (No. 22 on Map No. 1) which forms a high, nearly sheer fall over the eroded portion of the cliff in two or three leaps, but the stream usually contains too little water for its waterfall to be of any special interest. After long-continued rain there may also be two streams further West, one on each side of Red Cleave, but when this region was examined by the author their gullies were completely dry.

SHERRYCOMBE WATER.

The valley of Sherrycombe, immediately to the East of the Great Hangman, which can easily be followed from its source to its termination, is of great interest in comparison with that of the Heddon at Hunter's Inn, to which it presents a great similarity. The latter is, however, at base-level, while Sherrycombe Water is still some 500 feet above sea-level at less than three-quarters of a

mile from the waterfall at which the valley ends. To the West, its wall rises nearly sheer to the summit of the Great Hangman, 700 feet above, while the eastern wall, cut in Holdstone Down, is only a little lower. Its stream is above the average in size, and possesses no tributaries except at its source. It runs in a straight line almost due North, and ends in a fine fall, of something under a hundred feet in height, on to the beach. Only the top of the fall can be seen from the cliff. To see the fall itself we must take a boat along the coast from Combe Martin.

The fall lies in a small sea-cut gully, the walls of which are not quite vertical. The stream passes over the rocks in a direction contrary to the dip (*counterdip*), and its leap is somewhat broken by the unequal weathering of the beds. Near the top of the cliff, it divides into two small falls, which unite again lower down, and reach the beach as a long, semi-sheer fall, somewhat broken into cascades by ledges of harder rock projecting from the sloping cliff face. There is a distinct resemblance between this fall and that of Hollow Brook (p. 51) which is, however, much higher.

THE GREAT AND LITTLE HANGMAN.

One interesting feature of this high table-land is the weathering out of the more elevated portions into circular or nearly symmetrical hills. The

Great Hangman (1,044 feet) is perhaps the best example of this circumdenudation, and rises 400 feet above the general level of the surrounding moor. The Little Hangman (716 feet) is, however, scarcely less symmetrical. The northern flanks of both these hills are being rapidly denuded by the sea, though the sea has not yet cut through their crests. Further to the East, Holdstone Down (1,146 feet) and Trentishoe Burrows (1,061 feet) furnish other examples. These hills result from the unequal weathering of an elevated table-land, the Hangman Grits here being rather more resistant to denudation than those elsewhere.

THE ILFRACOMBE SECTION.

The Ilfracombe Section begins at Combe Martin, or more strictly speaking at the junction of the Hangman Grits and the Ilfracombe Beds at Wild Pear Beach, somewhat to the North of that village. In the northern corner of this beach, which is also known as West Challacombe Beach, the Hangman Grits end near the limekiln, and the Ilfracombe Beds are seen resting upon them. There is a fault, or probably a thrust plane, at the actual junction, and the beds on either side are much contorted. The relationships of the two series are thus not clearly seen. This junction is one of the very few on the North Devon coast which can be

reached without the aid of a boat. Near the junction the Ilfracombe Beds are fossiliferous, and contain the characteristic fossil, *Stringocephalus burtini*.

The Ilfracombe Series consists of bluish grey, or silvery slates and shales, with occasional thick bands of impure limestone. Beds of grit also occur here and there, and contain many quartz veins. While the slates are the dominant rocks, the limestone bands, though impersistent, are of importance, especially near Combe Martin and Ilfracombe, and they may be studied in numerous quarries along the main road between these two places. They contain a certain amount of silver-lead ore, formerly much worked at West Challacombe, and elsewhere near Combe Martin. The limestones are highly fossiliferous.

At Combe Martin they are rich in Corals and other fossils, the more important species being :—

Stromatoporoidea—
- *Stromatopora concentrica* Goldf.

Corals—
- *Cyathophyllum cæspitosum* Goldf.
- *Favosites fibrosa* (Goldf.).
- *Pachypora cervicornis* (Blainv.).
- *Heliolites porosa* (Goldf.).

Brachiopoda—
- *Stringocephalus burtini* Defr.

COMBE MARTIN.

With the incoming of the Ilfracombe Beds, we notice a distinct change in the features of the coast

Plate X

Lester Point, Combe Martin, looking North-east, from Combe Martin Beach (Ilfracombe Beds).

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scenery. The fine view, up and down the coast, from the summit of the Little Hangman gives us an excellent idea of the differences between the coast-lines of the Combe Martin and Ilfracombe Sections of this district. To the East, we see the Great Hangman and the greater part of the elevated range of magnificent Hog's-back cliffs, stretching to Heddon's Mouth. We also notice that the coast-line is but little indented, and is washed by the sea almost throughout its entire length at all states of the tide. To the West, we find that the cliffs are, as a whole, much lower, and while they still conform to the Hog's-back, and not to the Flat-topped type, their seaward slope is much more gradual, and their higher portions are, for the most part, cultivated. But even more striking is the difference in the form of the coast-line. Westwards the sea cliffs are broken into numerous sharp promontories, with narrow coves between, the whole forming a much indented coast-line. Here there is usually a beach between the points. The difference in the character of the rocks, and their different modes of weathering, is probably sufficient to account for the dissimilarities of these two shore-lines.

Two streams, the Umber and Newberry Water, enter the sea close together at Combe Martin. Both are at base-level, and further their terminations are drowned by the sea ; that is to say, the sea

has cut out and enlarged the cove in which the streams end. This is the first example of a drowned river mouth which we have met with along this coast. Others occur further West at Watermouth, and, in Cornwall, at Boscastle.

The marine erosion of the Ilfracombe Slates, on either side of Combe Martin Mouth, may be studied in detail with the aid of a boat, especially towards Lester Point (Plate X). Between Combe Martin and Watermouth, whether we journey by the road or along the coast in a boat, we obtain excellent views of the erosion of the slates forming the low cliffs in the numerous sharp prominences, and the jagged, angular reefs on the shore.

WATERMOUTH.

The small stream at Watermouth, though at base-level, is extremely interesting. Its termination (Plate XI) has been drowned by the sea, which has got into, scooped out and enlarged the mouth of the valley. It is the best example of a drowned river mouth to be met with in North Devon.

The valley of this stream at its seaward termination is roughly parallel to the general trend of the coast-line. Not only has the sea broken into its mouth, but its seaward or north-east wall, known as the Warren, is being

Plate XI

The Drowned River-mouth at Watermouth at low tide, looking North (Ilfracombe District).

[*To face p.* 60

vigorously attacked. Several great, sea-wrought gullies have been cut in it. One of these has penetrated right through, and has cut off an island, Sexton's Burrow, at the seaward end. Another has carved out a second island, Burrow Nose, from the north-east side of the wall. Further inland, near Watermouth Cave, several less advanced clefts have been driven into the wall, one of which, Small Mouth, has cut almost through it and is within some fifty yards of the stream, which it threatens to capture at no distant date. We have here an example of an early stage in the history of a sea-dissected valley, other more advanced instances of which will be discussed in Chapter X.

The western wall of this stream is also undergoing rapid marine erosion, on both sides of Widemouth Head, which some day will be isolated as an island.

WATERMOUTH CAVE.

The cave at Watermouth is one of the best examples of the many such caverns to be met with along this coast (Plate XII). The sea has here worked along some fault or other plane of weakness in the slates. It began by the enlargement of the fault, and by the working out, bed by bed, of the slates along the planes of cleavage, which are here highly inclined. Thus a great rift

was driven into the cliff, by the tearing out of several parallel beds of slate. These were broken off from the higher portions of the beds, which formed the roof, and remained unweakened by the attack of the sea. The roof of the cave has, however, subsequently fallen in two places, and thus two caves have been formed, the outer one of which is seen on Plate XII.

RILLAGE POINT.

Between Watermouth and Hele Mouth, there are very fine views of the sharp, jagged, eroded Ilfracombe slates, especially those gained from the extremity of Rillage Point, and from the east side of Hillsborough (Plate XIII). The cliffs here are low, but still of the Hog's-back type, though with a more gradual seaward slope than those further to the East.

West Hagginton Beach is famous for the variety of its rocks. Slates, limestones, shales and sandstones may all be studied here. The beds are intensely folded, and the limestone bands, broken by thrust faults, are repeated again and again. Fossils are abundant in some of the beds, and, for the most part, are similar to those found near Ilfracombe (see below).

The mouth of the stream entering the sea at Hele Beach is at base-level, and its seaward termination has been drained and altered artificially.

Watermouth Cave, looking seaward (Ilfracombe District).

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ILFRACOMBE.

The slates of the Ilfracombe Beds may be studied with advantage on the coast in the immediate neighbourhood of that town. Several good folds are to be seen by passing along the beach between the harbour and Hillsborough. In many places the slates exhibit the original planes of bedding, as well as those of cleavage, and near the bathing beaches may be observed interesting alterations in the beds as the result of the immense pressures to which they have been subjected.

The rocks, especially the limestone bands, are fossiliferous. The following are the chief species recorded :—

Corals—
- *Cyathophyllum cæspitosum* Goldf.
- *C. obtortum* Edw. and Haine.
- *Favosites fibrosa* (Goldf.).
- *Pachypora polymorpha* (Blainv.).

Polyzoa—
- *Fenestella arthritica* Phill.

Brachiopoda—
- *Atrypa reticularis* (Linn.).
- *Crytina heteroclita* (Defr.).
- *Spirifer curvatus* (Schloth.).
- *S. verneuilii* Murch.
- *Orthothetes crenistria* (Phill.).
- *Stringocephalus burtini* (Defr.).

Echinodermata—
- *Cyathocrinus variabilis* Phill.

Fish spines, bones and coprolites occur, but no scales or teeth.

Hillsborough, the prominent elevation to the East of Ilfracombe, is over 400 feet in height, and is interesting as an example of a hill which is being rapidly eroded by the sea on two sides. The sea has very nearly cut through its summit. The limestones and slates contain numerous Corals, Crinoids, and Brachiopods, which are for the most part the same as those indicated in the above list.

Capstone and Lantern Hills, which add so much to the picturesqueness of the "front" of Ilfracombe, are all that remains of the northern wall of the termination of the valley of the East Wilder Brook. The rest has been swept away by the sea, and these hills, which show some interesting rock-folds of a gentle nature, like the scenery of other parts of Ilfracombe, have been largely modified and "brought up to date" to meet the requirements of the host of visitors to this popular resort. The two streams which enter the sea at Ilfracombe, the East and West Wilder Brooks, have been drained and diverted long since. It is probable that formerly one, if not both of them, ended in coastal waterfalls of one type or another. They are certainly still above base-level at their mouths.

The rocks at the bathing place, and other localities close to Ilfracombe, offer splendid opportunities for the detailed study of the effect of folding and cleavage on interbedded limestones,

Plate XIII

Rillage Point and Hele Bay, near Ilfracombe, from Hillsborough, looking North-east. Sea erosion of the Ilfracombe Beds.

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shales and grits. Dr. Marr has pointed out that all stages can here be traced between gently folded bands of limestone and grit, and attenuated folds, with their middle limbs replaced by a thrust plane, and finally a schist-like rock with long drawn-out "eyes" of limestone. The quartz veins are also affected in the same way as the thin limestones.

To the West of Ilfracombe, the Torr's Walk, which is the northern wall (451 feet in height) of the valley of the West Wilder Brook, now being rapidly denuded by the sea, offers further opportunities for the study of the slates and limestone bands of the Ilfracombe Beds. The Hog's-back cliffs of the coast further west towards Lee can, however, only be studied with the aid of a boat, and present no special features of interest which cannot be more conveniently examined nearer Ilfracombe.

CHAPTER III

DISTRICT III.—THE MORTEHOE DISTRICT

THE third district in North Devon extends from Lee Bay, two miles West of Ilfracombe, to the estuary of the Torridge and Taw, at Braunton Burrows. It includes the three promontories, Bull, Morte, and Baggy Points, and the coast scenery is perhaps more varied in this district than in any other. On the other hand, the cliffs are low, and not very striking, except at the Points above mentioned.

The geological formations represented in this area are the Morte Slates of the Middle Devonian, which extend from Lee Mouth to Woolacombe, and the Pickwell Down Sandstones, the Baggy or *Cucullæa* Beds, and the Pilton Beds of the Upper Devonian, between Woolacombe and Braunton Burrows. There are also large stretches of blown sand of modern origin.

Headquarters.—A considerable choice of headquarters exists in this district. In the northern portion, Mortehoe or Woolacombe (or even Ilfracombe) are the most convenient, while in the southern half, Croyde or Saunton Sands (or even Barnstaple) are suitable centres.

Ilfracombe and Barnstaple are reached from Exeter and Taunton, as explained on p. 49. Mortehoe Station, on the Ilfracombe line, is two miles distant from Mortehoe or Woolacombe. Croyde Bay and Saunton Sands are reached from Braunton Station, on the same line, and are six, and two and three-quarter miles distant by the road respectively. Owing to the proximity of the Ilfracombe line to the coast, energetic walkers can explore the whole district from Ilfracombe or Barnstaple, by taking the train part of the way. The round from Ilfracombe to Mortehoe or Woolacombe by the coast, and thence inland to Mortehoe Station and rail to Ilfracombe, is not very strenuous; but that from Mortehoe Station to Woolacombe and across Woolacombe Sands to Baggy Point, and thence through Croyde and Saunton to Braunton Station is considerably longer.

Directions.—From Lee Mouth, the golf course may be avoided by taking the road to the South-west towards Damage Barton, and then bearing to the right, back to the cliffs. Or, if the tide is suitable, one may walk along the shore to the West as far as the little waterfall at Hilly Mouth, formed by the stream traversing the golf course, and then take to the cliffs. There is a cliff path straight from Hilly Mouth to Bull Point. The shore can be reached at Bennett's Mouth midway, and the Morte Slates studied for some little distance to the East and West.

From Bull Point to Rockham Beach there is no way along the cliffs which is not a trespass, and it may be necessary to make a long detour, following the carriage road from the Lighthouse to North Morte, whence there is a footpath to Rockham Beach. There is a path to the shore here, but the coast can only be explored for a very limited distance to the North or South.

The next promontory, Morte Point, has recently been bought and consecrated to the use of the general public, and, as a natural consequence, some of the approaches are now fenced in with formidable iron railings. There is no way from Rockham Bay to Morte Point, except by returning by the path, above mentioned, to North Morte, and then by the road to Mortehoe Church, where a fenced path begins which leads to the promontory. On

the south side of Morte Point, one can proceed along the cliff to the Mortehoe Hotel. The cliffs here are low, and the rough shore can be easily gained, especially near Mortehoe.

Between the Mortehoe Hotel and Woolacombe, the road follows the edge of the low cliff, and there is no difficulty in reaching the shore at any point that may be desired.

At Woolacombe the cliffs end, or, to put it more accurately, recede a considerable distance inland, and a long stretch (about two miles) of sandy beach intervenes, which extends as far as Baggy Point, and furnishes the best and most direct route to that promontory. At the southern end of the sands, the rocks of the eastern portion of the Point may be examined at low tide.

There are several ways over Baggy Point, which has cliffs ot the Hog's-back type on both sides. Perhaps the best is to take the rough road at Vention cottages, and bear to the right at the first opportunity, along a track following the crest of the ridge towards the end of the Point. Or, where the sands end, we can climb up for about 200 feet, and then follow the northern cliff to its westward termination. On the south-east side of Baggy Point, there is a well-kept path running above the sea-cut portion of the slope, and this leads to the main road to Croyde Bay. The shore can be reached without difficulty at several points on the way.

At Croyde Bay, the road makes a long detour inland, through Croyde Village. This can be saved by crossing Croyde Sands, and rejoining the road on the northern side of Saunton Down End. The road round Saunton Down has been cut in the cliff, and here, again, the beach is easily reached at several points.

The road now passes inland to Braunton, and we have before us the wide expanse of Braunton Burrows and Saunton Sands, extending as far as the estuary of the Torridge and Taw.

Maps.—Ordnance Survey :—

One-inch scale: Sheets No. 276 (Morte Point) and 292 (Baggy Point).

Six-inch scale: Devonshire—IV., N.E. (Ilfracombe, Lee); IV., N.W. (Bull and Morte Points); IV., S.W. (Woolacombe);

Plate XIV

Rockham Bay, near Bull Point, looking North. Erosion of Morte Slates (Mortehoe District).

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VIII., N.W. (Baggy Point and Croyde); VIII., S.W. (Saunton Sands and Braunton Burrows); XII., N.W. (Braunton Burrows and estuary of the Torridge and Taw). [VIII., S.E. Braunton (not the coast)].

The Mortehoe District may be conveniently divided into two sections, the Woolacombe Section from Lee Bay to Woolacombe, which consists of Morte Slates, and the Baggy Section from Woolacombe to Braunton Burrows, occupied by the Pickwell Down Sandstones and the Baggy and Pilton Beds.

THE WOOLACOMBE SECTION.

As we have just pointed out, the rocks of this Section consist entirely of Morte Slates, and it may be well here to add a few words on the position of these beds in the Devonian series, in addition to the brief account included in the Introduction (p. 6). The sequence of rocks, as there outlined, is still a matter of dispute. Some maintain the view, which is also provisionally adopted here, that the Morte Slates are of Middle Devonian age, and intermediate in position between the Ilfracombe Beds and the Pickwell Down Sandstones. But the physical structure of the rocks themselves is so complex, and they have undergone so much folding, faulting and contortion, that the question has been raised, whether the *apparent*

succession of the rocks, as seen along this coast, is the *real* sequence, or whether the Morte Slates are not of older date than the Ilfracombe Beds, and have not been thrust up over them from below.

Further, until comparatively recently, no fossils of any sort were known from these slates. About twenty years ago, however, Hicks obtained the first fauna from these beds, and this he regarded as of Silurian age. He explained the succession on the theory that the Silurian Morte Slates had been thrust up, from below, over the Middle Devonian Ilfracombe Beds. The fossils in question are somewhat crushed and fragmentary. Some observers deny that they are Silurian species, though they agree that they may be of Lower Devonian age, and that the Morte Slates are thus out of place in the series. The evidence for this view cannot, however, be regarded as conclusive as yet, and for the present the author is inclined to hold, provisionally, to the older theory, that the apparent sequence is the real succession, on the grounds that, however complicated the relationships of the individual beds to one another may be, the general primary synclinal structure of the whole area is perfectly simple.

Another and entirely different explanation was put forward many years ago by Jukes. Jukes postulated that a fault exists at Woolacombe, at the top of the Morte Slates, and that the Pickwell

Plate XV

Morte Point from Mortehoe, looking North-west. Erosion of Morte Slates.

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Down Sandstones, and the Baggy and Pilton Beds are merely a repetition of the series, beginning with the Foreland Grits and ending with the Morte Slates (*i. e.* the Lower and Middle Devonian) thrust up, and over, from the North to the South. In other words, the series of Devonian rocks from the Foreland to Woolacombe is repeated from Woolacombe to Barnstaple. This theory is now, however, generally discredited. Not only is there no trace of a fault or thrust at Woolacombe, but Etheridge has shown that the Baggy and Pilton Beds, to the South, contain an Upper Devonian fauna, as opposed to the Lower Devonian fauna of the Lynton series, and the Middle Devonian of the Ilfracombe Beds. For further information on this point the reader may be referred to the bibliography of geological memoirs at the end of the present volume.

The Morte Beds are pale grey, glossy slates, which exhibit a great abundance of very conspicuous white quartz veins. At first sight, they are not easy to distinguish from the slates of the Ilfracombe Beds. They are, however, characterized by their glossy texture, the abundant quartz, and the fact that no limestones are known to be associated with them. The position on the coast of the actual junction of the Ilfracombe and Morte Slates is placed by Hicks and Hall a little to the East of Flat Point, while others, especially

Etheridge, have regarded it as nearer Lee, and only a short distance East from Lee Mouth.

A little to the East of Lee, three greenstone dykes are said to occur on the shore, but they can only be examined at low water at spring tides.

The coast scenery of the area occupied by the Morte Slates is characteristic. The cliffs are much indented, though not deeply, and the reefs between tide marks consist of large masses of slates, tilted nearly vertical, and broken off above obliquely. The jagged reefs have very sharp edges (Plate LVIII and Plate LV, Fig. 1), hence they are often described locally as "the cruel Morte Slates." Their glistening surface, and the glaring nature of the quartz veins, adds to their uninviting appearance.

BULL POINT.

The first point of interest West of Lee Mouth, the stream of which is at base-level and drained, is the little brook traversing the golf course at Hilly Mouth. This is still several feet above sea-level at its termination, and ends in a small waterfall, divided into two branches, over the sloping face of the low cliff, which is here about 15 feet high. The falls are not sheer, but of the cascade type.

From the summit of Damagehue Cliff, we see some very fine jagged reefs along the shore, and to the West between us and Bull Point, the steep-sided valley of Bennett's Water (No. 34 on Map

Plate XVI

Vertical beds of slate at Morte Point overlain by a considerable thickness of "head." From the cliff, 50 feet above sea-level (Mortehoe District).

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No. 1). The lower portion of this valley (Plate LX) affords perhaps the best and simplest example of a stream at base-level at its mouth to be met with along these coasts. We notice how the valley, here nearly straight, widens and shallows towards its termination. The sea has, as yet, hardly worked into its mouth. The reefs seen at the left-hand lower corner of the photograph on Plate LX are those laid bare at low tide, and the white patch of shingle beyond them marks the place where the stream peacefully meets the sea, when the tide is up. In the background is the cliff of Bull Point.

Bull Point presents no features of particular interest beyond its jagged reefs. Like Hartland Point, it is really a right-angled turn in the coast, rather than a promontory, and in particular it is the western wall of the valley of Bennett's Water.

MORTE POINT.

At Rockham Bay (Plate XIV), South of Bull Point, a well-marked fold is seen on the north side, and there are some fine and high buttress-reefs, projecting from the cliff, which recall those formed by the shales and sandstones immediately to the South of Bude Harbour (p. 150). The fossil *Lingula mortensis* Hicks, has been collected here.

Morte Point is a real prominence, having the

form of an isosceles triangle. Its cliffs are low, and their slope is gradual (Plate XV). They approximate to the Hog's-back cliff type (p. 15), only the lower fifty feet or less being undercut by the sea. The rocks of the cliff, above the sea-cut portion, weather unevenly, and the harder beds tend to stand out as ruin-like masses, as in the case of the Valley of Rocks, near Lynton (p. 44), though here in less degree, and less conspicuously. The Point appears to have suffered much from aërial denudation, and the ridge, bisecting the triangle, has been much worn down. The slates are perfectly cleaved, highly tilted, often nearly vertical, and broken across with an oblique, angular, sharp fracture.

There is one particularly fine exposure of the slates in a gully on the southern side of the Point (Plate XVI). The beds here are nearly vertical, and lying upon them is some twenty feet of "*head*" or broken, displaced rock, which has slipped or moved into a horizontal position. This is seen at the top of the photograph on Plate XVI, on the right-hand side. This photograph may be compared with that on Plate XX, a similar section on Baggy Point, where, however, there is no "head" at the summit of the cliff.

Hicks obtained *Lingula mortensis* Hicks, on Morte Point, and the following fossils a little further South, between Crunta Beach (Morthoe Hotel) and Barracane Beach—

The former waterfall at Mortehoe, as it was in April 1908 (Mortehoe District).

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Rhynchonella cf. *lewisii* Davids.
Spirifer hamlingi Hicks.
Orthis rustica Sow.
Modiolopsis barracanensis Hicks.

His most important fossil locality in the Morte Slates was, however, at Mullacott Quarries on the road from Ilfracombe to Mortehoe Station, and about a quarter of a mile South of Ilfracombe Cemetery. Here, in addition to some of the above-mentioned species, he obtained—

Stricklandia lirata (Sow.).
Rhynchonella stricklandi ? (Sow.).
Cardiola interrupta ? Sow.
Pterinea mortensis Hicks.

Just below the Mortehoe Hotel, there is a stream (No. 35 on Map No. 1) which formerly formed an interesting waterfall, about fifty feet in height, at the head of a sea-cut gully. The photograph on Plate XVII shows the fall as it was in April 1908. The stream, however, has recently been drained, and the waterfall unfortunately no longer exists, and thus this photograph has an historic interest. We have here another example of how, during the "civilization" of a coast-line, natural features of interest are apt to disappear.

The reefs between Mortehoe and Woolacombe (Plate LVIII) are worthy of study, as examples of the "cruel Morte Slates." Traces of a raised beach (see p. 79) can also be detected here and there in the cliff above.

THE BAGGY SECTION.

At Woolacombe, we enter on a quite different type of scenery. The coast here is low, and the sandstone bluffs of Woolacombe and Pickwell Downs lie some distance back, and inland. Between the downs and the sea, there is a great accumulation of sand, and, at the foot of the downs, a line of dunes or hills of blown sand occurs (Plate XVIII). The sandhills are not, however, so large as those of Braunton Burrows, further South.

WOOLACOMBE.

The small stream at Woolacombe is at base-level, and its mouth is choked by sand. The approximate point, at which the Morte Slates pass under the Pickwell Down Sandstones, lies a short distance to the South. Students of Devonshire Geology will remember that this is also the "*line*" of the supposed fault of the late Prof. Beete Jukes (see p. 70), of which, however, there is no ocular evidence, at least on the coast. The junction of the two series is obscured by blown sand, and by the low-lying nature of the ground immediately bordering the coast. By studying the reefs, however, at low tides, it will be found that the Pickwell Down Sandstones come in a little to the South of Woolacombe, and the same beds may be

Plate XVIII

Woolacombe Sands, with a reef of Morte Slates in the foreground, and a range of sand dunes and Woolacombe Down in the background, looking East, away from the sea (Mortehoe District).

also examined in the quarries on Woolacombe Down. The photograph on Plate XVIII shows, in the foreground, one of the last reefs of the Morte Slates to the South of Woolacombe. Associated with these slates there are thin veins, up to four inches across, of an igneous rock, perhaps a greenstone.

The Pickwell Down Sandstones are reddish-brown or purplish grits, with micaceous sandstones and conglomerates, the total thickness being about 3,000 feet. The beds are unfossiliferous. They extend from Woolacombe to the southern flank of Baggy Point.

The coast along the whole of the Baggy Section has been raised within comparatively recent times. There is ocular evidence of this fact in the magnificent raised beach of Baggy Point and Saunton (pp. 79 and 82), which we shall discuss shortly. As the result of this elevation, the old cliff-line at Woolacombe has retreated inland, and is now separated from the present high-water mark by the gently shelving area of old sea-bottom, now raised to dry land. Owing to the removal of the cliffs out of reach of the sea, the supply of boulders derived from them by marine denudation has ceased, and such debris as once existed has long since been ground down to fine sand. Further, the promontory of Baggy Point cuts off the supply of boulder material from the South. The line of

dunes is an additional modification of the distribution of the sand, under the influence of wind. This will be discussed later, when we come to deal with the dunes of Braunton Burrows.

BAGGY POINT.

The fine promontory of Baggy Point is remarkable for its configuration. The northern flank is long and straight. At the end, there is a straight stretch of cliff with an aspect due West, while the third side, towards Croyde Sands, runs in a south-easterly direction. The Upper Devonian rocks of the Point consist of the Baggy, or *Cucullæa* Beds. At the eastern or inland extremity of the northern flank, the Pickwell Down Sandstones join on to the Baggy Beds, and, on the southern flank, the Pilton Beds come in.

The Baggy Beds are hard, flaggy sandstones and grits, interbedded with soft, olive-coloured shales, often rich in fossils, *Cucullæa trapezium* Sow. being particularly abundant; hence the name, sometimes used, "*Cucullæa* Beds."

Among the other fossils the following are the chief species:—

Cucullæa unilateralis Sow.
Orthoceras champernowni Whidb.
Orthoceras (?) *tentaculare* Phill.

A fish, *Holoptychus*, has also been obtained, and plant remains have also been recently collected from the quarry close to Croyde Hoe Farm.

Plate XIX

The Raised Beach, in the cliff on the South-east side of Baggy Point, resting on highly tilted Baggy Beds (Mortehoe District).

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THE RAISED BEACH.

From the northern end of Baggy Point, for a distance of at least three miles to the South, there is a series of sections of a magnificent Raised Beach to be seen in the cliffs, perhaps one of the finest-known examples of the kind. This beach represents the sand and shingle of a former shore-line, which has been raised above sea-level by a comparatively recent elevation of this portion of the coast. Such beaches afford one of the most convincing proofs that such elevations have taken place.

The beach is very well seen on the south-east side of Baggy Point (Plate XIX), where it is above the action of the waves at ordinary tides, except in times of storms. The cliffs of the Point, as we have shown, are of the Hog's-back type, only the base of the long, gentle, seaward slope being undercut by marine erosion. This eroded portion is only a few yards in height, and, resting unconformably on the upturned edges of the Upper Devonian rocks (Plates XIX and XXI), is a considerable thickness of horizontal Raised Beach. In the photograph on Plate XIX, large masses of the Beach, the stratification of which is very evident, are seen broken off from the cliff. That on Plate XXI is taken from the same position, but here the view is to the South-east towards Croyde.

The inclined Devonian beds are clearly seen, with the raised beach above, some blocks of which have become weathered out, and are lying loose. The gradual nature of the slope of the cliff is also shown here.

This raised beach has been known for many years past (see the bibliography at the end of this volume), and has been studied and described on several occasions. Its thickness is about twenty-five feet. It consists of false-bedded sands, with some water-worn pebbles. At its base there are several feet of coarse, hard shingle. Broken shells of the Cockle (*Cardium edule*), the Limpet (*Patella vulgaris*), and the Mussel (*Mytilus*), among others, are frequent in the lower portion of the beach, and *Cardium* also in the sands. As we shall see, this beach is even more remarkably developed at Saunton Down, beyond which it disappears under the sands of Braunton Burrows.

At the end of Baggy Point there is some fine rock scenery. The beds are here very highly inclined, being almost vertical (Plate XX), and the cliffs are without any "head" (cf. Plate XVI) or raised beach at their summit. The great slabs of sandstone, here rising sheer from the sea for nearly 200 feet, are very impressive.

A large cave exists at Baggy Hole, which can, however, only be reached from the sea, except at very low tides.

Plate XX

The sea erosion of highly tilted Baggy Beds at Baggy Point, looking West (Mortehoe District).

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On the southern flank of Baggy Point, there is a small stream, now drained to a tank, which must formerly have been of some little interest. It has not quite reached base-level at its mouth. It flows along the dip of the beds, and ends in a little sea-cut gully in the Pilton Beds, with a small two-foot fall near its termination. The conformable junction of the Baggy and Pilton Beds lies a short distance to the North-west of this stream, and near here several characteristic Pilton fossils have been found in the cliff, as well as flint implements.

SAUNTON DOWN.

Leaving Baggy Point, we proceed to Croyde Bay. Here we again meet with sands between the two headlands, as at Woolacombe. Behind the sands are "Burrows" of blown sand-hills, and further inland the land rises very gently to Croyde village, which is itself only about sixty feet above sea-level. Croyde Sands represent, in fact, the mouth of a river valley, the stream of which is quite at base-level, and has been drowned, so to speak, with blown sand, while Saunton Down and Baggy Point are the southern and northern walls of the valley, respectively.

The Pilton Beds, the highest division of the Upper Devonian, occupy part of the southern flank of Baggy Point, and the whole of Saunton Down End. In Croyde Bay, they consist of slates, with

beds of calcareous sandstone, and nodular bands of limestone, which are rich in fossils.

The chief species are :—

Trilobites—

Phacops latifrons (Bronn.).

Brachiopoda—

Strophalosia productoides (Murch.).
Athyris concentrica (v. Buch.).
Atrypa desquamata Sow.
Chonetes hardensis (Phill.).
Hypothyris pleurodon (Phill.).
Orthis granulosa Phill.
Spirifer verneuilii (Murch.).

Coral—

Cyathocrinus variabilis Phill.

Polyzoa—

Fenestella plebeia M'Coy.
Penniretipora bipinnata (Phill.).

The Pilton Beds, however, are best studied in the neighbourhood of Barnstaple.

Saunton Down End is worthy of detailed examination. Not only are magnificent sections to be seen of the Raised Beach, a continuation of that at Baggy Point (see p. 79), but the Pilton Beds are rich in fossils, and the rocks, as exposed in the reefs which continue right round this promontory as far as the Saunton Sands Hotel, show some good folds and contortions. One special object of interest, about a half-mile West of Saunton Hotel, is a large erratic boulder of red granite, resting on the platform of the raised beach, and embedded

Plate XXI

The Raised Beach on the South-east side of Baggy Point, overlying highly inclined Baggy Beds, looking South.
Saunton Down in the far distance.

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in the sands, above high-water mark. The boulder measures about $7 \times 5 \times 2$ feet, and is perfectly smooth and rounded. It is supposed to have been derived from Scotland. Another of whitish-grey, foliated granite, of about 18 cubic feet in size, lies on the foreshore on the south side of Croyde Bay. Such erratics are very rare elsewhere in Devonshire.

At Saunton Sands Hotel, the cliffs end and the land slopes gently inland, and we have before us the wide expanse of Saunton Sands and Braunton Burrows, stretching to the estuary of the Torridge and Taw. This is the largest area of sandy waste on the whole coast. The large sand dunes of the Burrows are a happy hunting-ground for the botanist. The accumulation of sand is due to the fact that cliffs are absent to the eastward, and that the whole land has been recently raised. Thus the supply of rocky material, from which the sand is derived, has long ceased, and, further, the estuary of the Torridge and Taw prevents the arrival of any fresh material from the South.

The estuary itself is blocked with blown sand, and thus a bar exists across the mouth of the river. The actual estuary probably lies on Lower Carboniferous rocks, but these are not seen in any cliffs bordering the sea. They are, however, exposed a little inland, in reefs on the shore of the Torridge, North of Instow, and are better studied on the left-hand bank of the Taw, between Frem-

ington and Barnstaple, and inland to the South of the latter, especially at Coddon Hill, where the famous Radiolarian chert beds are well exposed.

The sand dunes of Braunton Burrows are worthy of examination. It will be noticed that the majority face the South-west, the region of the prevalent winds on this coast. Further, the two sides of the dunes are dissimilar. On the seaward side, or weather quarter, there is a long gradual slope to the summit of the dunes. On the landward side, however, the slope is shorter and steeper, and the outline more concave. This is due to the production of swirling eddies on the sheltered side of the dune. The wind, passing over the crest, loses part of its velocity when it reaches the back of the dune, owing to the protection which the dune itself affords. Hence eddies are formed, which attack the landward face, and scoop out the sand, thus leaving a concave slope.

CHAPTER IV

DISTRICT IV.—THE CLOVELLY DISTRICT

The fourth District in North Devon stretches from the estuary of the Torridge and Taw to Hartland Point, and includes the greater portion of Bideford Bay. The cliff scenery is exceedingly fine, especially in the western portion of the District, from near Clovelly to Hartland Point. The cliffs are of the Flat-topped type throughout, except on the east side of Clovelly (the Hobby Drive).

The cliffs consist entirely of a single geological formation, the Upper Carboniferous, the beds, known in Devonshire as the Upper Culm Measures, being equivalent in age to the Middle Coal Measures of other districts in Britain. They consist of alternations of sandstone and shales. Sometimes the shales are thicker than the sandstones, and form the chief rock facies, as at Abbotsham Cliff, near Westward Ho!. In other places, sandstones predominate, as at Cockington Head. A third type occurs at Gallantry Bower, Clovelly, and at many other localities, where the alternating

beds of sandstone and shale are of nearly equal thickness, or as the geologist terms it—"*even-bedded*." Every variation in the relative thickness of the beds may be found at one spot or another, and no type is more characteristic of one region than another. All the beds are extremely inconstant, when traced laterally.

In addition, thin, impersistent bands of impure limestone (Plate XXIII) occur here and there, lenticular in form, of only a few feet in length and thinning out at either end to a thickness of an inch or so. Calcareous nodules, often of large size, and containing *Goniatites* and other marine organisms, are fairly abundant in certain beds of shale throughout the district. These nodules, in a water-worn condition, may be often picked up on the beach among the boulders of the pebble-ridges. They are then more or less rounded off and polished by sea erosion, and the *Goniatites* are more clearly seen.

Among the rolled pebbles of the beach, there will also occasionally be found some which contain a large number of small, black, lenticular objects, embedded in a fine-grained, grey sandstone (Plate XXII, Fig. 1). These black bodies are really fragments of plants, the structure of which has, to some extent, been preserved by an infiltration of the tissues by calcium carbonate. They are rolled, water-worn fragments of petrified vegetation, derived from pre-existing beds of Carboniferous age, out of

FIG. 1.—The boulders of a pebble ridge, showing the variation in size and in the position of rest. The pebbles are of sandstone, and have prominent quartz veins.

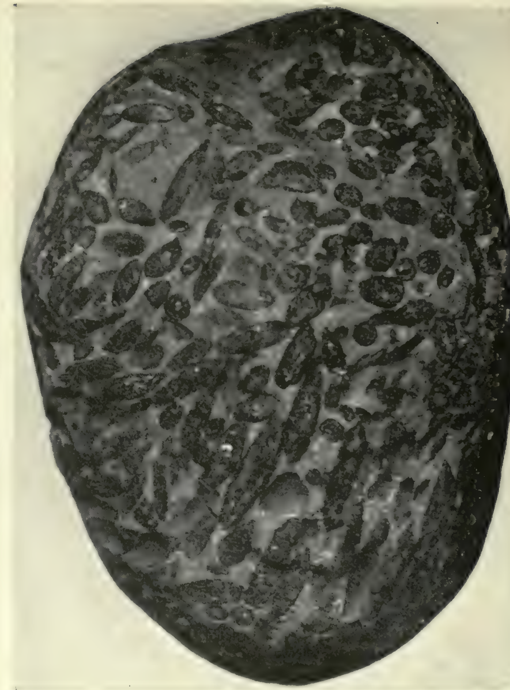

FIG. 2.—A rolled pebble of sandstone, containing numerous plant petrifactions.

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which they were washed, and shortly afterward re-deposited in the sandstones in which they are now found. The structure has unfortunately proved in all cases to be badly preserved, and so it has not been found possible to determine the class of plants to which they belong.

These petrifactions are distributed along the coast, though they are much less abundant than the calcareous nodules. They usually form layers, only a few inches in thickness in the sandstones, or more rarely in the shales, and are easily overlooked when *in situ* in the cliffs.

Headquarters.—The chief centres for examining this district are Westward Ho! or Bideford, preferably the latter, in the North, and Clovelly, which is considerably more than half-way towards Hartland Point. The main road from Bideford to Clovelly and Hartland runs more or less parallel to the coast, but at some little distance from it. It is generally necessary to follow this road for part of the distance between one point on the coast and another, and hence Bideford is, on the whole, a more convenient centre than Westward Ho!, except for the immediate neighbourhood of the Pebble Ridge.

Directions.—From Westward Ho! as far as the Hobby Drive at Clovelly, there is no difficulty in reaching the shore. There are good roads or tracks to the beach at Westward Ho! (road), Cornborough, Greenacliff, Cockington, Portledge (road), Peppercombe (road), and Buck's Mills (road). The best way to see the coast is to traverse the shore in sections, making use of the most convenient means of access above mentioned, all of which connect with the main road from Clovelly to Bideford or Westward Ho!, or its branch the Abbotsham road. There is no continuous cliff walk along this section of the coast, and in some places passing along the top of the cliff is a trespass. The shore, though strewn

with abundant pebbles, is smooth in comparison with other portions of the coast.

From the Hobby Drive, beyond Buck's Mills, past Clovelly and on to Mouthmill, the cliffs are private property and belong to Clovelly Court. The shore can, however, be reached at all three places, and it is not difficult, if the tide is suitable, to make a traverse along the beach between any two of them, though the "going" is distinctly rough in places.

The public are admitted on payment of a fee, either at the Bideford or Clovelly ends, to the Hobby Drive, the private road of this celebrated woody cliff. It affords some famous views, but the traveller, being restricted to the road, will see nothing of the cliff sections. This, however, is due to the fact that this stretch of cliff is of the Hog's-back type, as well as densely wooded with oak.

Beyond Clovelly street, the public are admitted on certain or all week-days, depending on the season, on payment of a fee, to the cliff walk from Clovelly to Mouthmill. This portion of the cliffs is of the Flat-topped variety, and as the path runs close to its edge, some excellent sections of the rocks below are to be seen. But here, again, a scramble along the shore offers much better opportunities of studying the cliffs. It may be added that the only way of reaching and returning from Mouthmill, which is not a trespass, or a right gained by the payment of a fee, is by both *going and returning* by the beach. Mouthmill is a terminus, except as regards the beach. It is thus best, perhaps, to go to Mouthmill by the cliff, armed with a ticket which gives one the liberty to return the same way, should the tide prove to be inconvenient or the beach too rough. Mouthmill, however, should on no account be omitted from the programme.

The section between Mouthmill and Hartland Point is more difficult of access, and is very little visited. There is no regular path along the cliffs, but the cliff-line can be reached at various points by pursuing the road from Clovelly to Hartland Town, and diverging to the North along one or other of the cart tracks (see the 6-inch map) leading to the farms situated not far from the

cliffs. With the consent of the farmer, one can then make across the fields to the cliffs. There are no paths down to the beach, but they can be descended here and there without much difficulty, and by means of a little scrambling. The author knows of at least two places on Fatacott and Gawlish Cliffs where the shore can be reached. It is best to proceed eastward and finish at Mouthmill.

Maps—Ordnance Survey :—

One-inch scale : Sheets 292 and 308.

Six-inch scale : Devonshire—Sheets XII[A]., S.E. + XII., S.W. (Northam and Westward Ho !) ; XVIII., N.E. (Cornborough and Abbotsham Cliffs, Greenacliff and Cockington Head) ; XVIII., S.E. (Portledge and Peppercombe Mouths) ; XVIII., S.W. (Buck's Mills and Clovelly) ; XVII., S.E. (Clovelly Court) ; XVII., N.E. (Mouthmill, Windbury Head, Exmansworthy Cliff) ; XVII., N.W. (Fatacott Cliff, Shipload Bay, Hartland Point).

The Clovelly District may be conveniently divided into two sections. The first of these, from Westward Ho ! to Buck's Mills, we may call the Bideford Section, while the coast-line stretching from Buck's Mills, past Clovelly to Hartland Point, may be termed the Mouthmill Section.

THE BIDEFORD SECTION.

This section begins at the estuary of the Torridge and the Taw, on the south side of which we find one of the most extraordinary features on the whole coast, the Pebble Ridge or "Popple" of Westward Ho!. To examine this in detail it is best to begin at the western extremity of Westward Ho !, where the cliffs come to an end.

THE PEBBLE RIDGE OF NORTHAM BURROWS.

Approaching Westward Ho! from the West, we find that the cliffs dip down and gradually disappear beneath the beach, and, in their place, a large bank of pebbles of all sizes begins, which soon turns to the northwards, and stretches in that direction for a considerable distance. The cliffs, along part of which Westward Ho! is built, seem to recede inland towards Northam, and between them and the pebble ridge there is a large triangular area of salt marsh with several pools of water. This marsh is bounded on the western side by the pebble ridge, on the north-eastern by the estuary of the united Torridge and Taw, and on the south-east by the rising ground and cliffs of Westward Ho!, Northam and Appledore.

The area known as Northam Burrows, or sometimes spoken of as the Westward Ho! golf links, has now a total extent of about 600 acres. At the northern extremity the beach curves round to the East in a hook-like form, and ends on Grey Sand Hill. In the hollow enclosed by the hook, Grey Sand Lake is situated. In recent years the sea has eaten away much of the land in this neighbourhood.

The Pebble Ridge, or "Popple," is a nearly straight bank of shingle, a mile and a quarter in length, and at least seven feet above the level of

the salt marsh behind it, and from ten to twelve feet above the sands on the seaward side. It varies from fifteen to twenty paces in breadth. It consists entirely of rolled boulders of different sizes, often quite large, which have been derived from the marine denudation of the cliffs towards Hartland Point, and have travelled along the coast westward to their present position. Pebble ridges are heaped up against the cliffs in many places between Hartland Point and Westward Ho! (Plate LVII) and especially under Cockington, Abbotsham and Cornborough Cliffs. These pebbles are on their way to renew and increase the ridge of Northam Burrows.

One of the chief points of interest with regard to the Pebble Ridge is that it has reared itself up at some considerable distance from the former shore-line, and between it and the ancient cliff-line there is the large stretch of flat ground of Northam Burrows, which has become enclosed with a wall of pebbles on its seaward side. The explanation is, however, simple. It is part of the same story as that of Braunton Burrows (p. 83), and the Raised Beach of Croyde and Baggy (p. 79). The land here has been raised, and part of the old sea-bottom has become dry land, over which the waves no longer break, and the old cliffs have thus receded inland. The pebbles, which travel up from the West, are deposited at high-water mark, which

is now some distance from the cliff. They further accumulate here, for the estuary of the Torridge and Taw is a barrier to their migration further North. Other examples of Pebble Ridges, which are even more famous, occur on other parts of the English coasts, as, for example, the Chesil Beach at Portland.

At one time the Pebble Ridge was more extensive than it is to-day, and the marsh behind it also, especially at its northern end. Early in the last century, the area of the latter probably exceeded a thousand acres, and the sea is said to be encroaching on the land at the rate of thirty feet a year. Between 1855 and 1861, no less than eighty-seven acres were destroyed. This, in part, has been due to the removal of the pebbles of the ridge for use as "road metal." In recent years a considerable outcry has been raised against this proceeding, and the removal of the pebbles is, we understand, now prohibited. It is also believed that the average size of the pebbles was formerly larger than it is to-day, and that they travelled up from the West in greater quantities than at present. This may perhaps be also partly accounted for by their removal — for a like purpose — further along the coast. At the same time the encroachment is probably due, in part at least, to the natural gain of the sea on the land, and were it not that the Burrows are an object of local pride,

on account of their picturesqueness, and their usefulness for the purposes of golf, probably little attention would have been paid to the matter. On the other hand, these changes are of interest to the geologist, for, with the exception of landslips, they are the only appreciable modifications which have taken place along the coast within the memory of the oldest generation,—so gradually do the forces of nature work.

THE SUBMERGED FOREST AT WESTWARD HO!

A submerged forest occurs at Westward Ho!, as also at Porlock in Somerset (see p. 34). About 400 yards on the seaward side of the Pebble Ridge, and near its western end, large beds of blue clay and peat are sometimes exposed after severe storms and high tides, when the accumulating sand has been scoured away. These beds have been described by Hall, and more recently by Rogers, as the Submerged Forest of Westward Ho!. In the clays, numerous stems of large trees occur, standing upright in the position in which they grew, but mostly broken off some two or three feet above their roots. One trunk has been described as six feet in circumference, another as twenty-two feet in length.

The beds of clay and peat were at one time four feet in thickness, but in recent years it appears

that only about a foot remains, owing to marine denudation.

In addition to stems and branches, the peat contains remains of Mosses, leaves of the Iris, Oak and Hazel, as well as the fruits of the latter trees, and large masses of roots and rootlets. Fruits and seeds of numerous other plants, such as those of the Alder, Violet, Elder, Sea Aster, Common Orache, Blackberry, Dogwood and Lesser Spearwort also occur. Shells of Oysters and Limpets are likewise frequent.

The blue clays yield flint flakes, possibly of the Neolithic period, and small pebbles and angular fragments of Carboniferous rock. Enormous quantities of the estuarine shell, *Hydrobia ulvæ*, also occur. Bones have also been obtained *in situ* in the clay including antlers, teeth and bones of the Red Deer (*Cervus elaphus*), as well as bones of Man, the Celtic Shorthorn (*Bos longifrons*), the Horse, Dog, Sheep, Goat, and Pig.

INSTOW.

In addition to the interesting geological features of Westward Ho!, we may briefly call attention to the Upper Carboniferous rocks of the estuary of the Torridge and Taw, which are worthy of examination. About a mile North of Instow, on the right bank of the Torridge, and almost exactly opposite the union of the Torridge and the Taw, a number of calcareous nodules have been found by Hall, and more recently by Rogers, embedded in the shales forming the reefs on the shore of this tidal estuary. Some of these nodules contain marine mollusca, while other very rare examples have yielded excellent specimens of fossil fish,

showing both the head and body. A few nodules also contain plant remains.

The following is a list of the species recorded :—

Plants—

Calamites suckowi Brongn.
Lepidodendron sp.
Cordaites sp.

Fish—

Cœlacanthus elegans (Newb.).
Elonichthys aitkeni Traq.

Cephalopoda—

Dimorphoceras gilbertsoni (Phill.).
Gastrioceras carbonarium (v. Buch.).
G. listeri (Martin).
Orthoceras morriscanum de Kon.

Lamellibranchia—

Posidoniella lævis (Brown).
Pterinopecten (Aviculopecten) papyraceus (Sow.).

Before leaving this neighbourhood we may call attention to the potter's clay deposits at Fremington, on the left bank of the Taw, a short distance from the coast. These beds were described many years ago by Maw, and also by Prestwich. They are probably an old series of lake deposits, like those of Bovey Tracey in South Devon. The age of the clays is unknown, but there is a suspicion that erratic blocks of glacial origin occasionally occur in association. If this is so, the beds are probably younger than the Glacial period. There are no Glacial Boulder Clays in

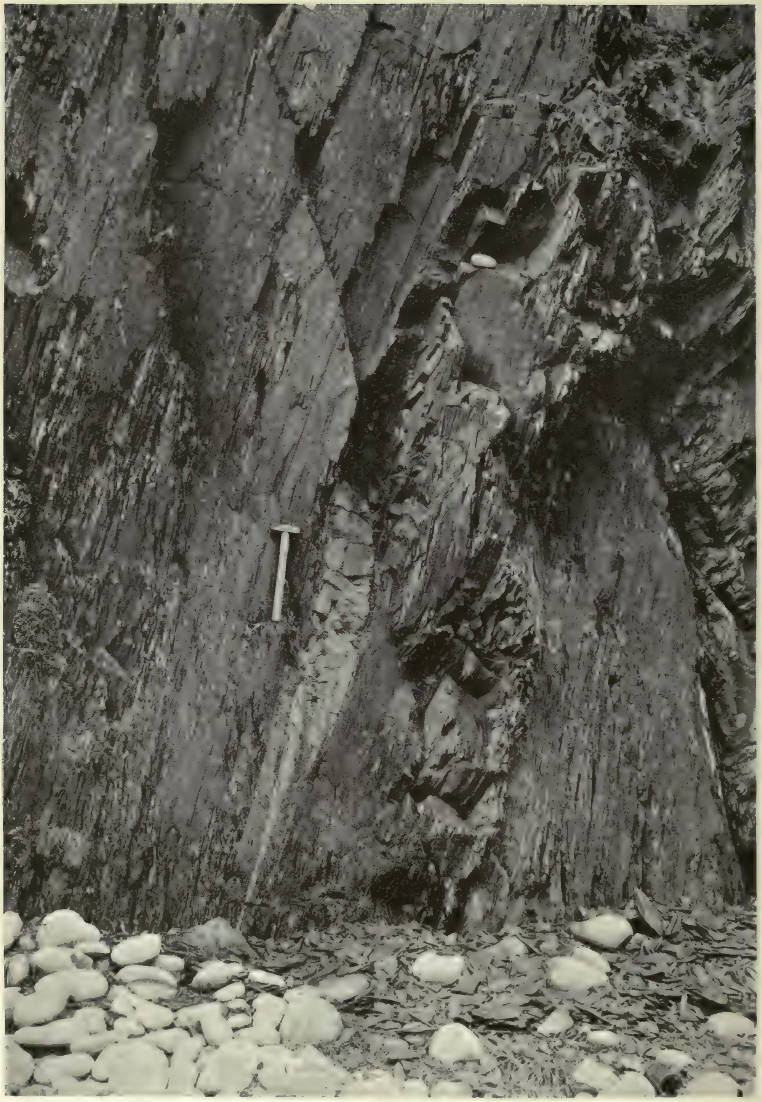
Devon or North Cornwall, and consequently the few instances in which erratic blocks have been recorded, as at Saunton (p. 82) and Fremington, are of great interest.

THE RAISED BEACH AT WESTWARD HO!

We now commence a study of the cliffs to the West of Westward Ho!, towards Buck's Mills. Where the cliffs begin to rise, we find a well-marked Raised Beach (indicated on the 6-inch map) at the summit of the low cliff, and 15 feet above the shore. The beach is from 5 to 10 feet thick, and above it 5 to 8 feet of broken debris or "*head*" is seen. It consists of large boulders, six inches across, with occasional flint nodules, but no shells occur. Otherwise it is similar to the raised beaches to be seen at Baggy Point (see p. 79) and Saunton (p. 82). We have here evidence that the coast-line has been raised within comparatively recent times.

Proceeding westward along Cornborough and Abbotsham Cliffs, a careful examination of the section will show that a large number of limestone bands (see p. 86) similar to that seen in the photograph on Plate XXIII, occur among the beds of shale. In Plate XXIII we see that the rocks are here tilted at a high angle. The limestone bed, which is white in colour, lies to the right of the hammer, which rests on the shales. The

Plate XXIII



A thin, lenticular band of Limestone, interbedded with highly inclined shales, in Cornborough Cliff, near Westward Ho! Upper Carboniferous rocks (Clovelly District).

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lenticular form of the band is well seen below. It ends above at the point where the pebble is seen perched up in the cliff.

The light fawn colour of the weathered surface of the limestone bands when dry, and their deeper brown colour when wet, renders them conspicuous among the shales to the trained eye, and at least twenty of these bands have now been located in these cliffs. These limestones are not of marine origin.

The only fossils they contain are plant remains, such as the pith casts of *Calamites*, and the fronds of *Alethopteris lonchitica* (Schl.). No *Goniatites* have ever been found in them.

ABBOTSHAM CLIFFS.

In another connection it may be well to study the beach below Abbotsham Cliffs at low tide. The photograph on Plate LVII shows the strong pebble ridge, heaped up by the waves against the cliffs, and seaward a nearly flat plane of marine denudation. The shales are here cut off almost level by the sea, with the exception of one or two reefs still projecting. The highly advanced stage in marine denudation seen here will be further discussed in Chapter VII.

At the south-west termination of Abbotsham Cliff we find the ruins of Greenacliff limekiln, beside a depression in which there is now no permanent stream. A few yards further South,

however, Greenacliff Water (No. 38 on Map No. 1) forms a sheer fall, about $15\frac{1}{2}$ feet in height, over the cliff into a little, sea-wrought gully. The beds here are tilted at an angle of 65°, and the fall is in the direction of the dip. In dry weather, however, the stream sometimes disappears almost entirely.

Having examined this stream, we will retrace our steps to the limekiln, and study in detail the beginning of Abbotsham Cliffs towards Westward Ho!. A few yards to the North of the limekiln, a seam of coal crops out in the cliff. The coal is termed in Devonshire "*culm.*" Although, geologically speaking, the greater portion of Devonshire and Cornwall is really a vast coalfield, it is destitute of coal with the exception of a few thin, impersistent bands, running inland on a line drawn from Greenacliff, through Bideford, for a distance of about twelve miles to Chittlehampton. The Greenacliff culm band, and a few very thin bands in Cornborough Cliff, are the only coal seams seen on the whole of this coast. The former seam was actually worked at Greenacliff in 1805, and traces of the rubbish heaps of the old workings can still be seen. The seam is about two feet in thickness. The section in the cliff is often more or less obscured by rain-wash, and the coal weathered to a black mud.

Another seam of culm has been worked for

many years past at Bideford, and the material raised—a fine, smutty, powdery coal in a natural state of slack—is still used as a basis for the manufacture of black paint. The tradition is that this substance was once much in demand for painting the three-decker wooden ships of the British Navy. Curiously enough, no coal seams have ever been found in the corresponding position on the southern side of the area, near Bude in Cornwall, as one would expect. Rumours of coal near Hartland, at a spot too promptly termed "Coalpit Lane," have proved to be baseless, and the Greenacliff and Cornborough bands are the only seams now actually to be seen at the surface in Devonshire.

The shales of Abbotsham Cliff, North of the culm band are very fossiliferous, though specimens are not easily obtained.

Rogers, in 1909 (see bibliography), published the details of a measured section, 143 yards in length, immediately north of the culm band, with a list of the records from each bed. Some of the shales contain plant remains alone, others freshwater mollusca, such as *Carbonicola acuta* and *C. aquilina*, which may or may not be associated with fossil plants. Other beds of shale are quite unfossiliferous. Calcareous nodules containing marine *Goniatites*, are, however, unknown here.

Among the plants are :—

Calamites ramosus (Artis).
C. suckowi Brongn.
Annularia radiata Brongn.
Sphenophyllum cuneifolium (Sternb.).
Pinnularia sp.

Alethopteris lonchitica (Schloth.).
A. serli (Brongn.).
Neuropteris schlehani Stur.
N. tenuifolia (Schloth.).
Mariopteris muricata (Schloth.).
Sphenopteris microcarpa ? Lesq.
Sigillaria sp.

This is a typical Middle Coal Measure flora.

A large fragment of fossil wood has also been found in the thick beds of sandstone immediately North of the culm band.

In examining this section it will be found that there is a remarkable variation in the character of the shale beds. Some shales break ovoidally, others into flakes or splinters. Some are sandy and micaceous and light in colour, others are purer shales, and dark in hue.

COCKINGTON HEAD.

We now continue westward to Cockington Head. The great feature of interest here is the very fine anticline known as Tut's Hole (Plate III). This is a sharp fold of a series of sandstone beds, some of which are four feet in thickness, projecting clear from the cliff. The anticline has become broken at its crest, and the sides are beginning to crumble away. In 1903, it measured fifty feet in height and seventy feet across the base.

Beyond Tut's Hole, but before Paddon's Path is reached, there occur beds of calcareous nodules in black sandy shales, high up (between 100 and

200 feet above the beach) in the cliff, which is here somewhat broken.

The nodules yield a marine fauna of *Goniatites*, etc., and the shales both fish remains and *Goniatites*. The marine fauna collected from these beds includes :—

Fish—

Elonichthys aitkeni Traq.

Cephalopoda—

Gastrioceras carbonarium (v. Buch).
G. listeri (Martin).
Dimorphoceras gilbertsoni (Phill.)
Orthoceras aciculare Hind.

Lamellibranchia—

Pterinopecten papyraceus (Sow.).
P. carbonarius Hind.
Posidoniella lævis (Bronn.)

The stream forming the steep-sided valley on the south side of Cockington Head (No. 39 on Map No. 1) by Paddon's Path, has practically reached base-level. The remains of a canyon, about sixty feet long and five feet in width, can be traced at its mouth, at the head of which a small four-foot fall occurs. The walls of this canyon are fifty feet or more in height.

A short distance further, calcareous nodules with *Goniatites* have been found on either side of Babbacombe Mouth, and also in the broken cliff of the Rowden.

PORTLEDGE AND PEPPERCOMBE

At Portledge Mouth (No. 40 on Map No. 1) the stream is at, or near, base-level, but its channel has been artificially dammed back to form an ornamental lake, and consequently the original condition, at its mouth, cannot now be ascertained.

Between Portledge and Peppercombe Mouths, the cliff section is of great interest. The rocks seen here are not of Carboniferous, but of Triassic, age. We have here an isolated remnant, or "outlier," as the geologist terms it, of the original covering of the Carboniferous rocks of Devonshire, now almost entirely removed by denudation, except in the eastern portion of the county. If we examine the Map No. 2, we shall see that a long tongue of Triassic rocks stretches West, through Crediton and central Devonshire to Hatherleigh. The outlier at Peppercombe, which is the only one to be found on the whole coast, has been cut off from the rest by the complete removal of the Triassic covering of western Devonshire.

The Trias at Peppercombe (Plate XXIV) consists of red conglomerates and marls, which are quite unfossiliferous, resting unconformably on the upturned edges of the Carboniferous sandstones and shales. There are two distinct areas of these red beds, that towards Peppercombe being said to contain irregular, concretionary masses of yellow magnesian limestone.

Plate XXIV

Peppercombe Fall, at Peppercombe Mouth (Clovelly District). Triassic rocks.

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The cliffs are low, shelving, and broken, and the rocks, except for their colour and geological age, are not particularly remarkable.

At Peppercombe Mouth, however, (No. 41 on Map No. 1), we find a waterfall actually cut in the Trias. The stream is small, though its valley is fairly deep. It rises near Horns Cross, and is only about two-thirds of a mile in length. For the greater portion of its course it runs over Carboniferous rocks, but, for about 150 yards from the beach, it flows over the Triassic outlier. It has not quite reached base-level at its mouth. It has cut down considerably into the low Triassic cliff, here, perhaps, twenty feet in height, and very broken and irregular. The stream (Plate XXIV) ends in a series of cascade falls, two to five feet high, on to the beach.

BUCK'S MILLS.

West of Peppercombe, the Carboniferous rocks are seen again, but the cliff section to Buck's Mills is of no particular interest, the slope being gentle and largely obscured by vegetation. One or two denuded anticlines are, however, seen on the beach.

At Buck's Mills (No. 42 on Map No. 1) we find a fine waterfall, which, unfortunately, is purely artificial. About a hundred years ago, it is said, the stream here was drained and diverted from its original bed, possibly in order to construct a

road to the beach and the limekilns, down its old canyon. The present fall is between thirty and forty feet in height, and in the last hundred years it appears to have cut down about eleven feet in the cliff. The stream was originally far above base-level at its mouth, and probably ended in a fall at the head of a canyon, but its real termination has been so altered artificially that it is very difficult, if not impossible, to ascertain what was the original state of affairs here.

THE MOUTHMILL SECTION.

Between Buck's Mills and Clovelly, the cliffs are uninteresting, and the shore is somewhat rough. The cliff-line, especially under the Hobby Drive, approximates to the Hog's-back type (p. 15), which we have become familiar with in the northern portion of the area. There is a long seaward slope, which is heavily wooded, and only undercut at the base by the sea to a comparatively small extent. In places the section is also much broken and concealed by vegetation. In wet weather four streams traverse this cliff. The two nearest Buck's Mills are usually very small and often dry, and thus of no particular interest. The next, which drains the eastern portion of the Hobby Drive (No. 43 on Map No 1), was found in 1908 to terminate in a landslip, through the foot of which

Plate XXV

Freshwater Fall at Clovelly.

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the water forced its way out, like a spring. If a waterfall once existed here, it has now been entirely obliterated.

There remains the "Freshwater Fall" of Kingsley's "*Westward Ho!*" close to Clovelly Pier (Plate XXV). This is the termination of a small stream, which ends in a fall of about forty-five feet in height. The cliff section is, however, sloping and much broken, and thus the stream, which divides into two branches, simply trickles down its face in a series of cascades over irregularities in the surface of the cliff. If the cliff section were here cut vertically by sea erosion, a much finer fall would undoubtedly be produced.

CLOVELLY.

The stream, which at one time flowed down Clovelly street, no doubt ended in a fine fall, somewhere near the view platform looking out over the little harbour. It is needless, perhaps, to add that this stream has long ago been diverted and drained, and the village, so picturesquely situated, has been actually built largely in its bed.

The beach to the West of Clovelly offers some very interesting examples of how the sea undermines the cliffs, and works out folded rocks. These should be carefully examined. A few paces westward of the pier, the excavation of beds of

shale in the cliff (Plates LII and LIII, see p. 188) by the sea can be well studied. Numerous calcareous nodules occur in the bed of shale (which is shown on Plate LIII) now being cut out by the sea. A little further on, we find an inclined fold or anticline (Plate XXVI), the heart of which has been removed by the sea. A synclinal fold is seen near by, and offers an interesting comparison. A little further on the beds are almost vertical, and the cliff is cut nearly sheer, except at the base, where a series of low buttresses project seawards.

GALLANTRY BOWER.

Under Gallantry Bower, and further westward, several beds containing large calcareous nodules, bearing *Goniatites*, are conspicuous in the cliff, embedded in the black shales. The geologist will also find of interest the bed of limestone occurring in the cliff, about 300 yards East of Blackchurch Rock and Mouthmill. This band, which the inexperienced may find some little difficulty in locating, was the first marine limestone band discovered in the Upper Carboniferous rocks of North Devon, and was described by Mr. Rogers and the author in 1894. A small anticline is here seen in the cliff facing East, the crest of which is formed by a dark-coloured limestone, nine to twenty inches in thickness, resting on a thick bed of shales containing numerous calcareous nodules.

Plate XXVI

A sea-eroded, inclined fold to the West of Clovelly.

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Both the Mouthmill limestone band (as it may be called) and the nodules below contain a marine fauna, of which the following are the chief fossils :—

Gastrioceras carbonarium (v. Buch).
G. listeri (Martin).
Dimorphoceras gilbertsoni (Phill.).
Orthoceras striolatum (Meyer).
Pterinopecten (Aviculopecten) papyraceus (Sow.).

MOUTHMILL.

Mouthmill is an exceedingly pretty spot. The large stream which here enters the sea, is at base-level at its mouth, and is of no particular interest. Blackchurch Rock (Plate XXVII), however, which is close by, is not only a picturesque reef, but is worthy of study as an example of an advanced stage in the marine erosion of a syncline. It is really a large "stack," situated between high and low water marks, which has become completely cut off from the cliff by sea erosion. It is part of the limb of a syncline, the beds being highly tilted, and the strike-face fronting the ocean. The sea, as is its wont, has worked round it at the sides, and not only has it isolated part of the limb of the syncline by working along some bedding plane, but it has cut two tunnels completely through the stack. The western ends of these tunnels are clearly seen in the photograph on Plate XXVII.

Blackchurch Rock should be examined at low

tide from all sides, as an example of sea carving. Between it and the land, there will be seen the "heart" of the same synclinal fold (Fig. 5), with broken beds sticking out on each side, like the ribs of some wreck cast on shore. Thus, while part of

FIG. 5.—The heart of a syncline as a reef on the shore, beside Blackchurch Rock, Mouthmill.

the seaward limb of this syncline remains as the isolated stack, Blackchurch Rock, the heart of the same fold, is also isolated, and much of the landward limb can still be traced in the cliff.

The long stretch of coast between Mouthmill

Plate XXVII

Blackchurch Rock, Mouthmill, near Clovelly.

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and Hartland Point is difficult of access, and is not known to present any rock sections of particular interest. Some good examples of folds occur here and there, such as the anticline and syncline shown on Plate XXVIII, which lie at the western end of Brownsham Cliff, a short distance from Mouthmill. There is only one stream, Beckland Water (No. 47 on Map No. 1), along this portion of the coast, and this forms a small waterfall a little further on, on the east side of Windbury Head. The stream, however, usually possesses very little water, and what there is merely trickles over the broken surface of the cliff in driblets, so the waterfall is hardly worth a visit.

Calcareous nodules have been found on the west side of Windbury Head, in Beckland Bay. At North Cliff near Hartland Point, there are some interesting folded rocks to be seen.

LUNDY ISLAND.

Lundy Island, which is so conspicuous from Hartland Point (from which it lies about twelve miles distant) as well as from the cliffs of Bideford Bay and those of the Mortehoe District, South of Bull Point, is remarkable for being the only island along the coast-line. It consists of granite, with the exception of a small area of Palæozoic rocks, possibly of Upper Devonian age, at the South-eastern extremity, including Rat Island. The

author has not visited its cliffs, which are said to be of interest. The island represents all that is left of a former great extension of Devonshire to the West, and demonstrates the large area of land, which has been removed by sea erosion, since Lundy became cut off from the mainland. The existence of Lundy to-day is due to the superior resistance to erosion of the hard granite rock, of which it is chiefly composed.

Plate XXVIII

An anticline and syncline in Brownsham Cliff, near Mouthmill (Clovelly District).

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CHAPTER V

DISTRICT V.—THE HARTLAND DISTRICT

This district lies partly in West Devon and partly in North-west Cornwall, the Marsland valley being the county boundary. It extends from Hartland Point to Bude. It includes the grandest, wildest and most remote cliff scenery in the whole area, the lofty Flat-topped cliffs being continuous throughout.

This district, like the last, consists of alternating beds of sandstones and shales of Upper Carboniferous age (see p. 85).

Headquarters.—The hotel at the foot of the cliff at Hartland Quay, two miles South of Hartland Point, and two and a half miles West of Hartland Town, is the most convenient centre in the northern part of the District. Bude is the corresponding centre at the southern end. Between the two there is no public accommodation near the coast, except at the small inn at Morwenstow. It should, however, be remembered that exceedingly good and comfortable, if somewhat rough, accommodation can often be obtained at a large number of farms, situated within easy reach of the sea, and such quarters are by many preferred to hotels, and are more in keeping with the wildness and remoteness of the spot.

It may be worth while mentioning a simple method of finding farmhouse lodgings in a district with which one is not familiar. The six-inch ordnance map gives the names of the farms, and a reply postcard may be addressed to "the occupier" of such and such a farm, which from the map is seen to be situated in the particular locality where lodgings are required, asking him if he knows of any farm in his neighbourhood where accommodation can be procured. As often as not it will be found that rooms can be had either at the farm chosen, or at one near by, of which the name and address of the occupier will be sent.

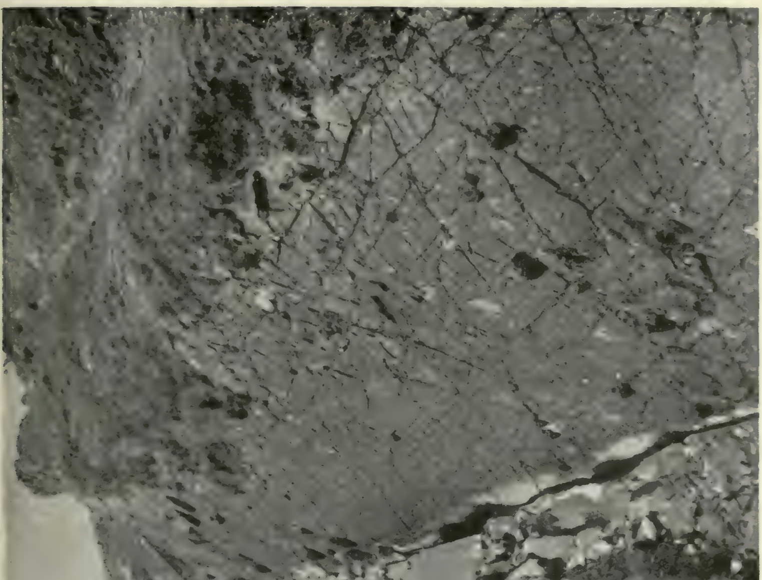
Hartland Quay is usually reached by driving (three hours) from Bideford, which is on the L. & S. W. Railway from London, Exeter, and Barnstaple to Torrington. There is also a Post-office mail brake twice a day from Bideford, via Clovelly Cross, to Hartland Town, where one can arrange to be met by a trap from the Hartland Quay hotel. This is a cheap and rapid means of reaching Hartland, provided one is only encumbered with a small amount of luggage. There are also carriers' carts to Hartland Town on certain days in the week, which may be patronized, but they are very slow.

Bude is reached by the L. & S. W. Railway from Exeter, Okehampton and Halwill Junction. Hartland Quay is about the same distance from Bude as from Bideford, *i.e.* a three hours' drive, but some of the places in this district are more easily reached from Bude than from Bideford, via Clovelly Cross.

The grandest cliff scenery in the whole area is between Hartland Point and Morwenstow. Immediately North of Bude the cliffs are low, and not particularly interesting for some distance.

Directions.—From Hartland Point to Bude, there is an almost continous cliff path, which affords excellent views of the coast. In the northern part of the district, the shore-line can be reached at the mouths of Titchberry and Blegberry Waters, at Blackpool Mill Mouth, and on the north side of Hartland Quay.

Plate XXIX



Blegberry Water, above the Fall, looking seaward (Hartland District).

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From the first-mentioned mouth, the shore northwards so far as Hartland Quay may be explored. From Blegberry Mouth, the foot of the cliffs may be traversed to the North as far as Dame Hole Point (Smoothlands), and to the South, to the Abbey River at Blackpool Mill. Blackpool Mill can only be reached from Hartland Quay (or via Stoke Church), or from Blegberry Water and Berry Cliff on the North, by the cliff paths. The grounds, through which this stream flows above its mouth, are private, and belong to Hartland Abbey. South of Hartland Quay Hotel, we can only follow the cliff path. The author, after many attempts, has been unable to reach any part of the shore-line, North of Speke's Mill Beach. Here there are two paths down to the beach, one close to the waterfall, and Arthur's Path, further North.

From Speke's Mill Mouth, the cliff path bends inland a little at the back of Longpeak, but soon regains the crest of the cliff, along which it continues almost to Welcombe Mouth. Near Knaphead, however, it is quicker to take the path bearing inland to the left, which leads down to Knap and Strawberry Water, a short distance from Welcombe Mouth. The shore-line between Longpeak and Welcombe Mouth, can be explored from the Mouth northwards, but not within the limits of a single tide. It is possible to get up and down the intervening cliffs with ease at Broadbench Cove, and with more difficulty at Dixonswell, from Elmscott Beach, further North.

Marsland Mouth, the county boundary, is a short distance South of Welcombe Mouth. The cliffs between the two should be avoided, and the road over the hill from Strawberry Water via Mead should be taken, or the rough but short stretch of beach between the two mouths may be easily negotiated.

From Marsland Mouth, the cliff path may be regained and followed, up and down, to Morwenstow. It is not possible to get very far southward from Marsland Mouth along the beach. The very rough point under Marsland Cliff has to be negotiated, and while one may proceed further past Litter Fall under Cornakey Cliff, for some little distance, it is not possible

to regain the cliffs further to the southward, and the tides, at the point above mentioned, only permit of a very limited stay on the south side of it. In the author's experience it is impossible to explore the shore between Litter Mouth and Stanbury Mouth, which lies to the North of Lower Sharpnose Point. There is now no path leading to the beach at any point in this stretch of coast, and the cliffs are almost everywhere perpendicular.

Beyond Morwenstow, we follow the cliff to Stanbury Mouth, where there is a road down to the shore, by means of which the limited stretch of beach between Hippa Rock (on the North) and Lower Sharpnose Point may be examined.

From Stanbury Mouth, the cliff path continues to Coombe Mouth, where there is another road to the shore. It is, however, difficult to get round Steeple Point along the beach to the North, or Warren Point to the South, and thus the means of access to the shore at Coombe Mouth is of little use for exploring the coast by means of the beach.

From Coombe Mouth to Northcott Mouth the path keeps some distance inland, but it is always quite possible to follow the coast-line by the cliff edge, though it is perhaps a trespass. The line of the cliff becomes lower and lower towards Northcott Mouth and Bude. The cliffs, however, are very interesting as seen from the beach, which is comparatively smooth going, and can be reached with ease at Sandy Mouth, Northcott Mouth and Bude. At Bude itself the cliffs end, and a half-mile or more of blown sand intervenes, before they begin again to the South of the little harbour.

Maps.—One-inch Ordnance Survey : Sheets 292 (Hartland Point to Warren Cliff), 308 (Warren Cliff to Marsland Mouth), 307 (Morwenstow to Bude, coast only).

Six-inch Ordnance Survey : Devonshire—XVII., N.W. (Hartland Point); XVII., S.W. (Hartland Quay); XXVII., N.W. (Elmscott Beach); XXVI., N.E. (Nabor Point and Broadbench Cove); XXVI., S.E. + *Cornwall I.* (Welcombe and Marsland Mouths).

Cornwall—I. N.E. (Welcombe and Marsland Mouths); I.

Plate XXX

The head of the Fall of Blegberry Water (Hartland District) from the top of the cliff, looking seaward.

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S.W. and S.E. (Morwenstow); III. N.W. and S.E. (Coombe); III. S.E. (Bude).

The fourteen miles or more of coast-line of the Hartland District may be conveniently divided into two sections of nearly equal extent. The more northerly extends from Hartland Point to Marsland Mouth, the county boundary, and the southern from Marsland Mouth to Bude. The first we will call the Hartland Quay Section, the second the Bude Section.

THE HARTLAND QUAY SECTION.

The Hartland Quay Section includes some seven miles of the wildest and grandest cliff scenery to be met with in the whole of Devon. The geological features of its coasts are as interesting as any to be found in the whole district, and in its coastal waterfalls it is believed to be quite unique, so far as Britain is concerned. The latter, alone, merit a visit to its shores.

Hartland Point is really a right-angle turn in the coast-line, in conformity with a change in the direction of the main watershed. It is not a long promontory stretching out to sea. The cliff, which is 300 feet high at the Marconi signal station, is cut almost at right angles on two sides by marine erosion, and from the angle a sharp ridge, or reef, projects seaward to the North-west,

on the lower portion of which the Lighthouse is placed. Otherwise the Point possesses no particular geological interest.

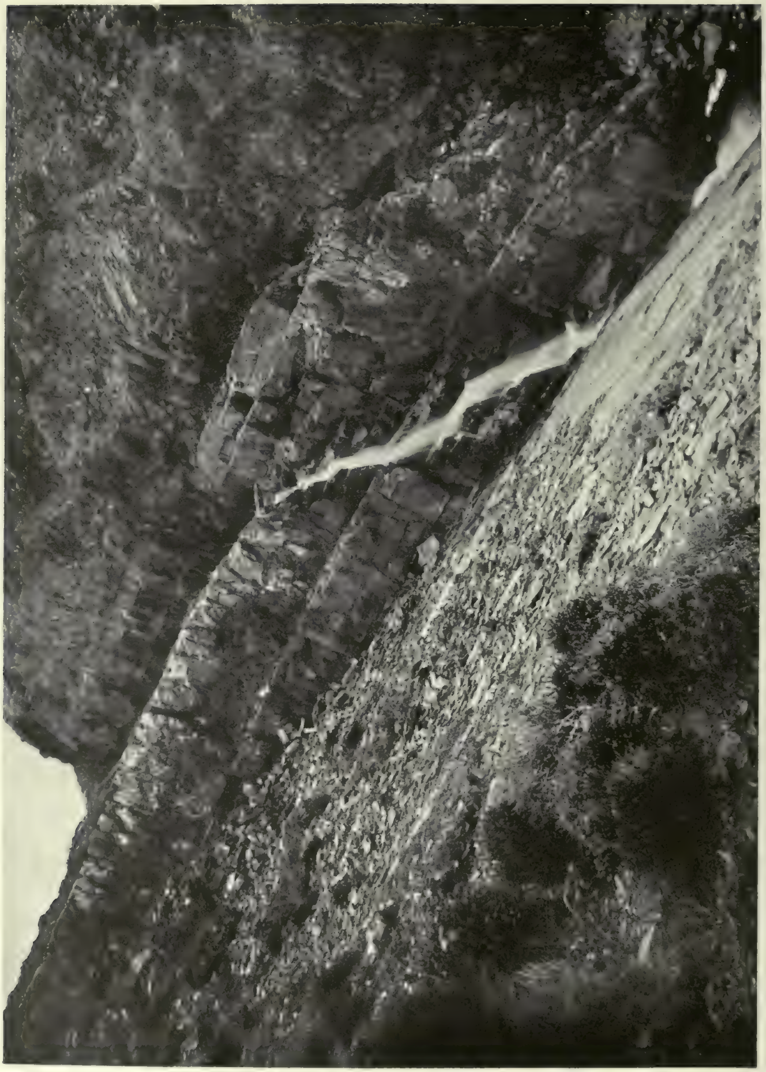
So far as the first stream, Titchberry Water (No. 48 on Map No. 1), about three-quarters of a mile South of Hartland Point, the coast-line of Blagdon and Upright Cliffs, which are between 200 and 300 feet in height, is not of any special interest. The rocks here, as elsewhere to the South, consist of alternations of beds of sandstone and shale, usually highly inclined. Several seams of shale with plant petrifactions (p. 86), or calcareous nodules containing *Goniatites*, have been located in them.

TITCHBERRY WATER.

The seaward termination of Titchberry Water is extremely interesting. It is a fair-sized stream, rising near Exmansworthy, two and three-quarter miles distant, and fed by several tributaries. There is a small waterfall near its mouth, at the head of a canyon, about sixty yards in length, which has been largely destroyed by landslips on either side (Plate XXXI). The canyon is cut in a syncline.

The stream immediately above the fall is flowing along the strike, and over a limb of an anticline, dipping southward at an angle of 37°. It has cut down into the parting of shale between two sandstone beds, and thus has undermined the sandstones lying above, and cut sideways into the

Plate XXXI



Titchberry Water Fall, South of Hartland Point.

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limb of the anticline. This undercut is clearly indicated at the head of the fall as seen in the photograph on Plate XXXI. The upper portion is a strike fall over inclined beds, small cascades being formed by irregularities in the hardness of the rocks over which the water passes. This portion of the fall is of the modified sheer-fall type (see p. 213). Below, however, the direction of the stream changes to the dip slope, along a bed of shale, and a gutter fall has resulted whereby the stream reaches the canyon, the landslipped walls of which are shown in photograph on Plate XXXI.

In the possession of a canyon, between the fall and the sea, this stream resembles the Abbey River, which reaches the coast a little distance to the South, though there the canyon is much better preserved.

SMOOTHLANDS.

Looking seaward from the cliff on the northern side of the canyon of Titchberry Water, we see to the South (Frontispiece) a flat piece of cliff, beyond which there is what appears to be an elevated, triangular hill, washed by the sea. This is the very interesting region known as Smoothlands. In passing we may also notice (Frontispiece) that, at the northern extremity of Smoothlands, the sea has cut out certain beds of the limb of a syncline, and left curved reefs of sandstones,

projecting like the ribs of some large wreck stranded on the shore.

In order to examine Smoothlands at close quarters, we cross Titchberry Water above the fall, and climb the steep southern wall of its valley. From the top of this cliff we see that Smoothlands (Fig. 12) consists of a level portion, running approximately North and South, parallel to the sea, bounded by a steep cliff on the inland side, and seawards by part of an equally abrupt cliff now being rapidly attacked by the sea. Smoothlands is, in fact, what we shall here call a sea-dissected valley, cut off at its northern and southern extremity by the sea. We will reserve for Chapter X a fuller account of its origin, especially in relation to other examples of such valleys to be met with along these coasts. We will, however, anticipate here so far as to add that Smoothlands is really a continuation of the valley of Titchberry Water (Fig. 12), which has become cut off by the sea, and beheaded, as it were, at a point where the stream of the Titchberry valley turned parallel to the coast.

Thus the peculiar features of Smoothlands, as seen from the present mouth of Titchberry Water (Frontispiece), are the flat, and now streamless, floor of the old termination of this valley, with part of the old valley wall on the seaward side.

Before leaving Smoothlands, some of the sea-

Plate XXXII

Blegberry Water Fall, South of Hartland Point, from the beach, in April 1910.

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cut gullies in its northern and southern terminations should be examined. These afford excellent illustrations of how the sea works at the rocks of a cliff, cutting out the softer beds, and slowly eroding the harder sandstones.

BLEGBERRY WATER.

Leaving Smoothlands, and passing over Blegberry Cliff, we soon find ourselves at another small stream, Blegberry Water. From this point we may explore northwards along the shore of Blegberry Beach, as far as Smoothlands (Dame Hole Point). The beds here are for the most part inclined at a high angle, and some very fair, though not perhaps remarkable, anticlines may be traced. Several of the shale beds contain calcareous nodules.

Blegberry Water (No. 49 on Map No. 1) is a small stream, about a mile and a half in length, which forms a waterfall at its mouth, though of a quite different type to that at Titchberry Mouth to the North, or the Abbey River to the South. This fall is very important theoretically, since it furnishes a key to the interpretation of the structure of the compound falls of Milford Water at Speke's Mill Mouth (p. 125).

Above the present waterfall (Plate XXIX) the stream is flowing along the strike of beds dipping 50° South. The beds are thin sandstones, alternat-

ing with very thin shales. The water flows over the basset edges of these beds, and has cut deep down into the bed of shale, which is so prominent on Plate XXIX, on the right of the stream. The head of the fall is also seen in the distance in this photograph.

In 1907, the stream, at the end of the cliff, bifurcated through two joints in the sandstones, and ended in two falls, one to the North, which was much the larger, and one to the South. In 1910, when the photograph on Plate XXX was taken, the channel of the smaller southern branch had become choked with debris fallen from the steep walls of the valley, and thus the northern branch carried off all the water over the cliff.

As viewed from the beach (Plate XXXII) we see that the cliff is being rapidly denuded by the sea, though it is to some extent protected by a large pebble ridge. The cliff is here about twenty-five feet high, and is the limb of a synclinal fold, as is clearly seen at the right-hand side of the photograph. This photograph was also taken in 1910, when only one waterfall was in existence. The other fall, then extinct, came over the cliff to the right of the existing fall, at the lowest point in the sky-line of the cliff, seen in the photograph, and flowed over the broad white, vertical streak seen to the right.

The fall at Blegberry Mouth is a sheer fall in the direction of the dip (dip fall), but owing to the

Plate XXXIII

The Fall of the Abbey River, at Blackpool Mill (Hartland District).

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fact that the beds over which it passes are inclined, it is broken into cascades or leaps (Plate XXXII) formed by the unequal erosion of the cliff, due to the existence of some hard, and therefore less easily eroded, beds. We have here an excellent example of how a fall, where the cliff over which it passes is not vertical, but inclined, tends to degenerate from a sheer leap into a broken sequence of cascades from one ledge to another.

THE ABBEY RIVER.

A very short stretch of cliff (Berry Cliff), of no particular interest, intervenes between Blegberry Water and Blackpool Mill at the mouth of the Abbey River (No. 50 on Map No. 1). This stream is only a fair-sized brook, perhaps a little larger than its neighbours to the North and South. It is, however, the longest stream on this section of the coast, rising near Clovelly Dykes, and having a total length of five and a half miles. Near its mouth, but some little distance from the beach, it forms a picturesque waterfall, at the head of a well-preserved canyon (Plate XXXIII). It offers one of the best examples to be found on these coasts of the mature canyon stage in the evolution of a waterfall (see p. 215). The fall is about fourteen feet in length, and in a direction contrary to the dip (*i. e.* counterdip). It is broken into steps or cascades by beds of sandstone, one of which, between two

and three feet in height, forms the top of the fall, and is just seen in the photograph on Plate XXXIII. Below the fall there is a pool, and then a canyon leading to the beach. The canyon, which is sixty-four yards long, and has walls about fifteen feet high, is not quite straight, and as viewed from the shore (Plate XLIV, Fig. 1) the waterfall, at its head, is hidden by a curve in the gorge. The canyon has been cut by the stream's erosion along the strike of an anticline, consisting chiefly of sandstones, the shale partings between the sandstone beds having formed the initial planes of weakness as regards erosion.

WARREN CLIFF.

The stretch of Warren Cliff between Blackpool Mill and Hartland Quay Hotel affords magnificent rock scenery, and should be examined from the beach, although the "going" is distinctly rough. Rock folding and the sea erosion of folded rocks are here very strikingly displayed (Plate LIV). A short distance to the South of the Abbey River and Dyer's Lookout, there is a very fine syncline followed by an anticline, the latter being compound, and consisting of several folds or contortions (Plate XXXIV). The crest of this anticline stands out very sharply from the cliff. The base of the syncline has been cut away by the sea more

Plate XXXIV

Folded rocks in Warren Cliff, North of Hartland Quay.

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vertically than that of the anticline, and this is often the case along this coast.

Further to the South are several other examples of anticlinal folds, one of which (Plate XLIV, Fig. 2) is very sharp, the two limbs forming an extremely acute angle. The sea has hollowed out a cave in its base, and the way the waves erode such folds is well seen to the left of the photograph. Next we find a very rounded anticline (Plate I), one of the most open curves met with on this coast. Here, again, the sea has eaten out the lowest beds of sandstones exposed in the cliff, and a dome-shaped cave or cavern is being initiated.

Close to Hartland Quay (Plate VI, p. 16), quite a number of regular anticlines and synclines can be seen, following one another, in the vertical face of the Flat-topped cliffs.

At various points along Warren Cliff, beds of plant petrifactions and calcareous nodules, similar to those already described (p. 86) may be found.

HARTLAND QUAY.

To the South of Hartland Quay, the grandeur of the rocks laid bare in the cliffs by sea erosion, and of the reefs on the shore, almost defies description. It is, perhaps, the finest scenery in the whole stretch of this coast-line.

The cliff, between Hartland Quay and the first stream to the South (Wargery Water), is very

interesting. The flat expanse below the path is really the original valley of Wargery Water (Fig. 11 on p. 232), which at this point ran parallel to the shore towards Hartland Quay. All that now remains of this valley is part of its floor and its seaward wall, which can still be traced in the small promontories at Screda Point, and between that point and the waterfall. The sea has not only devoured this wall, but cut great gullies through it, reaching, in some cases, to the centre of the valley (Plate LXIII). One of these gullies has captured the stream of this valley, just on the north side of St. Catherine's Tor. The wall on the landward side, *i. e.* the cliff along which the path winds, is still intact. This is another case of a sea-dissected valley, and will be more fully discussed in Chapter X.

WARGERY WATER.

Wargery Water is a small stream, a little over a mile and a quarter in length. It possesses several tributaries. Its waterfall, in its essential features, resembles that at Titchberry Mouth (p. 116). It is a strike fall over inclined beds. It starts with a sheer leap (Plate LXI), and then runs down the dip of a bed of sandstone for some little distance as a gutter fall. It next takes another sheer leap, and finally reaches the beach by flowing along the dip of a bed of shale. The chief differences between it and the fall at Titch-

Plate XXXV

Speke's Mill Beach, and the southern aspect of St. Catherine's Tor, from the cliffs above Speke's Mill Mouth, looking North (Hartland District).

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berry Mouth are that it lies at the head of a sea-cut gully, whereas the latter fall is at the head of a stream-eroded canyon.

ST. CATHERINE'S TOR.

Southward beyond Wargery Water, we see St. Catherine's Tor, a bold cliff (Plate XXXV), which is really a seaward wall of a tributary valley of Wargery Water, now beheaded by the sea and quite dry. This wall is being rapidly denuded on the seaward side, though the landward side is 270 feet high and quite intact, even more so, in fact, than Smoothlands (p. 118). This is another instance of a sea-dissected valley (see p. 233), but in this case the head, and not the foot, has disappeared beneath the Atlantic. The photograph on Plate XXXV shows St. Catherine's Tor, as seen from the South at Speke's Mill Mouth, with Speke's Mill Beach in the foreground. The sea-eroded wall is well seen, the landward grassy slope being in the shade. The line of fencing, to the right of the Tor, marks where the tributary valley has been beheaded by the sea. The rocks in the distance are those of Screda Point.

SPEKE'S MILL WATERFALL.

A short distance South of St. Catherine's Tor, Milford Water (No. 52 on Map No. 1) forms at Speke's Mill Mouth by far the grandest and most

imposing waterfall, or, rather, series of falls, on the whole coast. Many hours may be profitably spent in exploring and studying the wonders of these extraordinary falls, and with a little agility every part of the stream can be reached, either from the cliff above, or the shore below. Undoubtedly, when the existence of this fall becomes better known, it will be an object of pilgrimage.

Milford Water is a fair-sized stream, and, though

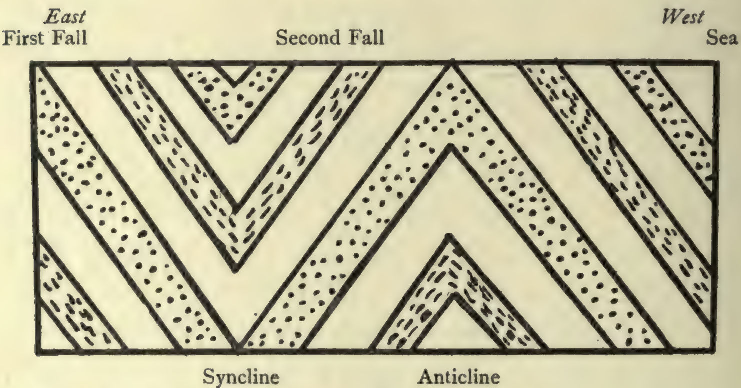

Fig. 6.—A diagrammatic vertical section of the rocks at Speke's Mill Mouth.

not a river, it probably has a larger volume of water than the other streams in this section of the coast. It rises near Tosberry, and has a total length of three and a half miles, two important tributaries joining it near Milford. The termination of its valley is relatively broad, and its sides are not nearly so steep as those of the majority of Devonshire combes. The photograph on Plate XXXVI gives a good idea of its seaward extremity.

Plate XXXVI

The valley of Milford Water and the head of the First Fall, from the cliffs above Speke's Mill Mouth, looking East (Hartland District).

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The first fall at Speke's Mill occurs at some little distance from the sea. The key to the structure of the whole series of falls is to be found in the fact that, between the first fall and the shore, the rocks are folded, and we have first a syncline, and then, towards the sea an anticline, as is shown in the diagrammatic vertical section, Fig. 6. There are four falls in all, of which the first, *i.e.* the farthest from the shore, is the longest. We will begin by enumerating the chief features of these four falls.

Plate XXXVII shows the head of the first fall, which is about 160 feet above sea-level. This fall is 53 feet 9 inches in length, and ends in a pool about eight feet deep. Its whole length is here seen in full face, so to speak, and in profile in Plate XXXVIII, Fig. 1. In the latter photograph the synclinal fold of the rocks, down which it flows, is evident, and this is obviously a dip fall. From the pool the stream turns at right angles, in the direction of the strike, and forms what will here be termed a gutter fall, in the heart of the syncline (B–C on Fig. 7). This gutter fall is 132 feet in length, and slopes gently towards the South. From a comparison of Plate XXXVI and Plate XXXVIII, Fig. 2, the latter showing the gutter fall, it is apparent that the stream has cut down the arm of a syncline in the direction of the strike, along an enormous bed of shale, the top and bottom of which are seen in these photographs. This gutter fall is older than the first fall. As the stream

has cut down along the strike, so the length of the first or dip fall has increased. At the end of the gutter (the point C in Fig. 7) the stream turns at right angles, and regains the dip direction, and cuts its way seaward through the anticline (Fig. 7). This turn or change of direction is well seen in Plate XXXVIII, Fig. 2. Between this point and the sea

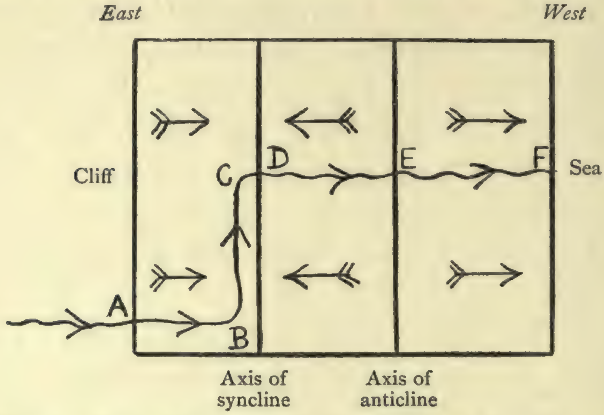

FIG. 7.—Plan of Speke's Mill Mouth Waterfall. (Not to scale.)

the stream has cut a canyon (C–F in Fig. 7), which is not yet mature, for it has neither reached base-level at its foot nor at its head. This most remarkable and beautiful instance of an immature canyon is seen in Plate LIX, where the photograph (taken from the point C in Fig. 7) shows the view from the right-angle turn looking seaward *down* the canyon, and also in Plate XXXIX, which is the view from the beach looking *up* the canyon.

At a distance of nineteen feet from the right-

The First Fall of Milford Water at Speke's Mill Mouth (Hartland District).

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angle turn (C in Fig. 7), the second fall occurs, twenty feet in length (Plate LXII) in a direction contrary to the dip (counterdip) over the landward limb of the anticline (Fig. 6). This fall ends in a pool, thirty-five feet across, cut out in the direction of the strike. The stream then flows in the direction of the dip of the seaward limb of the anticline (Figs. 6, 7) and a small inclined fall, the third, nine feet in length, is initiated. Some sixty-six feet further seaward, the fourth and last fall, 11 feet in height, is seen leading directly to the shore (Plate XXXIX).

We have thus four falls or, if we count the gutter fall, five; three of which belong to the canyon, the first being the longest. Such is briefly the outline of this most remarkable compound waterfall. Let us now examine each stage, and each fall, more closely.

We will begin with the first fall and the gutter fall, which form naturally the first half of this compound waterfall. There is a striking similarity between this part of the fall, and that at Titchberry Mouth (p. 116). The chief differences are that here the first sheer fall is a dip fall, and the gutter fall is a strike fall, whereas at Titchberry Mouth we meet with just the reverse. The canyon at Titchberry Mouth is also mature, whereas at Speke's Mill Fall it is very immature.

The initiation of this, the first part of the fall

at Speke's Mill, was due originally to the fact that, at the head of the present first fall, the stream began to cut down along the strike of a homogeneous bed of shale, thrown up nearly vertically, in the landward limb of a syncline, and thus, as we have said, the first fall was initiated, and later grew step by step, as the gutter fall deepened. The extraordinary preservation to-day of this enormous smooth slab of shale, which in places must be over 100 feet in height, and at least 150 feet in length, is not the least remarkable feature presented by this fall, especially since the seaward wall of the gutter fall, which is much broken and landslipped, is now much lower than its original height. An earlier but precisely similar stage may be studied above the fall at Blegberry Water (p. 119, Plate XXIX), where a long, strike gutter is also being cut against a bed of shale, now at least ten feet high in places. If it is doubted that this enormous mass of shale at Speke's Mill was exposed as the result of stream erosion, and not by landslips or other causes, a study of the gutter above Blegberry Fall will soon show that the view here expressed is the correct one.

Returning to the first fall we find it has cut down some nine feet in the bed of the hanging valley, which is here approximately 160 feet above sea-level.

The second portion of the waterfall consists of

FIG. 1.—The First Fall of Milford Water and the synclinal fold, looking North.

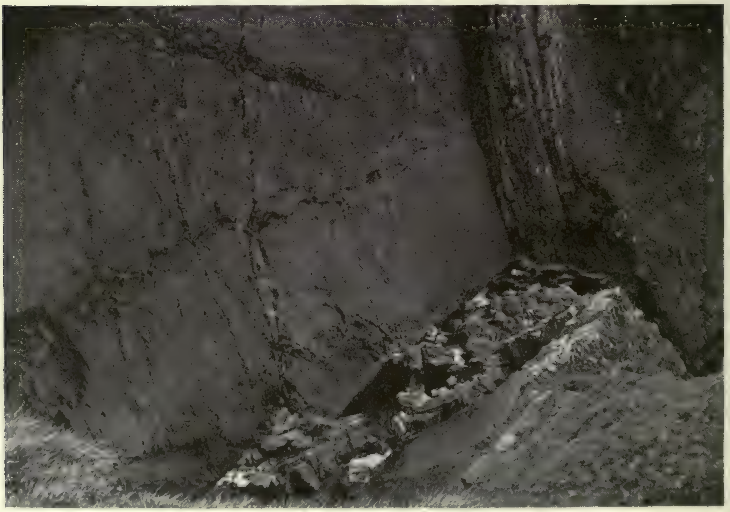

FIG. 2.—The Gutter Fall and the right-angle turn below the First Fall of Milford Water, looking South.

[To face p. 131

the canyon with its three small falls. Originally there was only one fall sheer on to the beach, in a position high above the present fourth fall. But this fall cut back and downwards in its bed, and owing to the unequal hardness of the sandstones and shales, and also to the difference in the dip, resulting from the anticlinal fold, it now consists of three falls with small cascades between them.

The point at which the gutter fall turns seawards (C in Fig. 7) was, no doubt, originally determined by the existence of a joint, or plane of weakness, in the seaward wall of the gutter, through which the water found it easier to cut its way, than to increase the length of the gutter. This joint of course occurred high (perhaps fifty or sixty feet) above the level of the present right-angle turn. The new direction of the fall, initiated by means of this joint, has since been steadily maintained.

In the future, provided the sea does not invade, erode, or interfere with the canyon, the canyon will be completed, and a single fall like that of the Abbey River (p. 121) will exist at its head. In the meanwhile the gutter fall will be gradually lowered, and the first fall increased in length, provided that it does not cut down rapidly in the head of the cliff.

Speke's Mill Fall is a very exceptional case of a series of waterfalls over folded rocks under a

special set of circumstances, the factors controlling which are so nicely balanced, that each stage is progressing nearly equally. It is of such special interest to the geologist, and such a wonderful sight for the wayfarer, that it would be well if it were acquired for the nation, and to some extent protected and kept in repair in so far as and only in so far as it is necessary to keep out the sea from the canyon, and to prevent landslips from the walls of the gutter fall and the canyon. The rate of change in this fall is probably comparatively rapid, as compared with most geological changes, such as those produced by coast erosion, and in a few generations, if left to itself, it will probably have reached a further stage in its evolution.

SPEKE'S MILL BEACH.

The shales exposed in the cliff at Speke's Mill Beach contain fossil plant impressions.

The following species have been recorded :—

Calamocladus cf. *C. equisetiformis* (Schl.).
Annularia ? sp.
Sphenophyllum sp.
Alethopteris lonchitica (Schl.).
Mariopteris muricata (Schl.).
Lepidophyllum ? sp.
Stigmaria sp.

NABOR POINT.

The greater part of the five miles of coast-line, between Speke's Mill Mouth and Welcombe, can

Plate XXXIX

The canyon of Milford Water, with the Second and Fourth Falls, from the beach, looking East (Hartland District).

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only be examined from the cliff-top. The author has failed to get round Longpeak by the shore, though Brownspear Beach may be reached from Speke's Mill Mouth. From Welcombe Mouth, it is possible to examine the base of the cliffs for a considerable distance to the North, as far as Elmscott Gutter, but, between Elmscott Beach and Longpeak, the coast remains unexplored so far as the shore is concerned. The rock sections are, however, very well seen from the cliff-top. Sometimes the beds, which here consist of sandstones and shales in layers of nearly equal thickness, are only gently inclined, though excellent examples of folded beds, especially anticlines, are to be found here and there, particularly at Nabor Point. At this promontory, and also at Sandhole Beach, a little further to the North, several beds containing calcareous nodules, with a marine fauna, and also plant petrifactions (p. 86) have been located.

The south side of Nabor Point should certainly be examined from the shore. There is no path down the landslipped cliff above Broadbench Cove, but it is quite easy, with a little care and circumspection, to descend to the beach at this place. Near low water, Ramtor Rock, at the northern extremity of Broadbench Cove, may be passed, and in the cliff of the next little bay, the magnificent contortions shown on Plate XL may be studied. These are the finest examples of contorted rocks to

be found for many miles up or down this coast. Several faults are seen in the cliff, and thus the folds, which consist of alternate layers of sandstones and shales of nearly equal thickness, are thrown into indescribable confusion.

These contortions (Plate XL) occur low down in the cliff. Others are seen high up near the top of the cliff, and other folds also occur below the summit of the cliff in Broadbench Cove. In a small bay to the South of Broadbench Cove, large calcareous nodules, containing *Goniatites*, are well seen in the cliff.

Knap Head, further South, the beach of which is easily reached from Welcombe Mouth, exhibits some very striking rock scenery and rock structures.

WELCOMBE MOUTH.

We now reach Welcombe Mouth, where Strawberry Water (No. 53 on Map No. 1), a fair-sized stream, with a length of over two miles, ends in a coastal fall, quite different in its physiognomy from any other which we have so far described (Plate XLI and Plate XLV, Fig. 1). It is a very interesting fact that Strawberry, Marsland, and Litter Waters, all close together and flowing in parallel valleys, should terminate in waterfalls so distinct from one another.

The fall at Strawberry Water is seen from above in Plate XLI, and from the beach in Plate XLV,

Plate XL

Contorted sandstones and shales at Broadbench Cove, South of Nabor Point
(Hartland District).

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Fig. 1. It is a somewhat complicated fall, its main features being determined by the enlargement of joints in the rocks over which the stream passes. It lies at the head of a sea-cut gully (Plate XLV, Fig. 1), which superficially somewhat resembles a river-cut canyon.

Above the fall, the stream is flowing along the strike of folded beds. In fact, the water passes over the basset edges of the beds forming the southern limb of an anticline, the plan of which is well seen in the reefs on the shore (in the background of the photograph on Plate XLI). The rocks here consist of alternating beds of sandstones and shales of nearly equal thickness.

Before the brook reaches the edge of the sea-cut cliff, it forms a pool, the overflow of which works its way laterally through joints in the upturned sandstones, in a northerly direction, in two or three places, the number depending on the amount of water in the stream. Two or three cascades are thus formed over the counterdip, basset surfaces of the sandstone beds, as is clearly seen in Plate XLI. These cascades are dissimilar in size and direction.

The one furthest from the sea works down, for 16 feet 3 inches, through joints, and ends in a long pool in the direction of the strike, which also receives a leak from the second cascade. The course soon changes to the strike, and this branch

ends on the beach as a small fall cutting into a bed of shale (seen on the left of the photograph on Plate XLV, Fig. 1).

The second cascade, on the seaward side, is the longer of the two, and originates beyond (seaward of) the pool at the top of the fall. It is a compound fall. The highest part, 8 feet 3 inches in length, crosses about six beds of sandstone, and ends in a small strike pool, which finds an outlet through enlarged joints on the seaward side. Maintaining the strike direction, it ends in three cascades of 13, $9\frac{1}{2}$ and $10\frac{1}{4}$ feet in length, two of which are seen in the photograph on Plate XLV, Fig. 1.

The short section of cliff between Welcombe and Marsland Mouths shows several folds, especially anticlines, which are not, however, very striking, and scarcely repay the toil of traversing this rough piece of beach.

MARSLAND MOUTH.

At Marsland Mouth, Marsland Water (No. 54 on Map No. 1), which, in this region, divides Devon from Cornwall, enters the sea. The lower part of this beautiful valley is exceedingly interesting from a geological point of view. Its stream is somewhat above the average in size, and has a total length of four miles. At its mouth, it has reached base-level. Its waterfall

Plate XLI

The top of the Fall of Strawberry Water at Welcombe Mouth, from the cliff looking seaward (Hartland District).

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is now degraded, and has retreated inland for at least a quarter of a mile. It is reduced to a few cascades, some three or four feet high, situated near the mill. Between the mill and the mouth of the stream, a fine canyon once existed, parts of which are still well preserved, though here and there its walls have fallen in, or decayed into sloping, grassy banks. The photograph on Plate XLIII, taken above the mill, shows the winding course of the stream, and portions of the vertical walls of its canyon. The canyon here is much larger, and more winding, but less well preserved than in the case of the Abbey River at Blackpool Mill (p. 121).

THE BUDE SECTION.

The Bude Section of the Hartland District, stretching from Marsland Mouth to Bude, lies wholly in Cornwall, and contains some very fine cliff scenery and some interesting waterfalls. A short distance South of the county frontier of Marsland Water, Litter Water forms a fine fall, between Marsland and Cornakey cliffs.

LITTER WATER.

Litter Fall is best seen from the beach, but it is hard work and very rough "going" to reach it by the shore, the passage across the long point of

Marsland cliff being difficult, though it is a delightful scramble and well worth the trouble. There is also a fine, unsymmetrical anticlinal fold to be seen in the cliff, just North of the fall.

Litter Water (No. 55 on Map No. 1) ends in an exceedingly interesting waterfall, showing the simplest and earliest stage in the evolution of a coastal fall, to which we shall refer again in a later chapter (p. 211). The stream is not very large, and has a total length of about one and three-quarter miles. Where it passes over the cliff to the shore (Plate XLII) it forms a sheer fall of about seventy feet in height. The rocks here are tilted nearly perpendicular, and the cliff is being cut back very rapidly, and nearly vertically, by the sea. The sheet of water is continuous, and not broken into leaps, as is usually the case, where the beds are inclined. In this respect, Litter Mouth resembles the highest fall at Speke's Mill (p. 127). As is evident from the photograph on Plate XLII, the stream at the head of the fall has cut down some little distance into the cliff.

YEOL AND MORWENSTOW WATERS.

The cliff between Litter Fall and Higher Sharpnose Point cannot, in the author's experience, be examined from the shore, unless with the aid of a boat from some distance up or down the

Litter Fall, to the South of Marsland Mouth (Hartland District).

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coast. In this portion of the coast-line we are thus restricted to the cliff paths.

The first point of interest to the southward is Yeol Water (No. 56 on Map No. 1), about half-a-mile beyond Litter Water. This is a very small stream, which in summer usually contains very little water. It ends in a waterfall, the head of which can be gained, but the author has not found any means of reaching its foot, and thus the physiognomy of the fall remains unknown.

Passing over Henna Cliff, we find ourselves close to the little hamlet of Morwenstow, famous for the parson poet, Hawker, for many years incumbent of the parish. In the valley on the north side of the church, there is a small stream, Morwenstow Water (No 57 on Map No. 1), which ends in a waterfall of considerable height over the cliff. The fall cannot, however, be seen from above, and the author, after repeated attempts, has failed to reach the beach in its proximity, and thus its features remain for the present unknown.

We next pass along Vicarage Cliff, until we reach the path to Hawker's Hut, over the land-slipped portion of the cliff. There is, however, no way to the shore here. The former path has fallen into disrepair, and ends in space. From the landslip, however, looking South, the fine promontory of Higher Sharpnose Point is well seen.

THE TIDNA.

We next reach the Point, which has very fine cliff scenery on both sides. On the North, Higher Sharpnose Point is bounded by the very steep-sided valley of the Tidna (No. 58 on Map. No. 1), a small stream which runs right out to near the end of the promontory. It there terminates in a most curious waterfall, the whole of which is visible from the cliff, though the shore-line here cannot be reached without the aid of a boat.

The Tidna Fall is a typical gutter fall. Where the stream approaches the cliff, it is running along the strike of a limb of an anticline, dipping southward at about 30°. The cliff, which is here over sixty feet high, is sheer cut by the sea, and one would naturally expect to find that the stream dashed over it as a sheer fall. However, it does nothing of the sort. At the very brink of the cliff, it turns to the South very sharply, almost at right angles, and flows down the dip surface of the cliff, cutting out a gutter in a bed of shale (Fig. 8, A–B). This gutter is forty-three feet in length, the bottom being about twenty feet below the top. It is so well cut that it is easy to climb down it.

At the bottom of the gutter, the stream turns towards the sea, and having cut a passage through the seaward wall of the gutter, along the strike (Fig. 8, B–C) by enlarging the joints in the

Plate XLIII

The termination of the Marsland valley, looking seaward (Hartland District)

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sandstones, it tumbles over the cliff as a sheer fall, 40 feet 9 inches in length. The cliff over which the lower part of the fall takes place is being rapidly eroded by the sea. This fall illustrates very clearly the influence of joints, and of highly inclined beds, on the physiognomy of a waterfall.

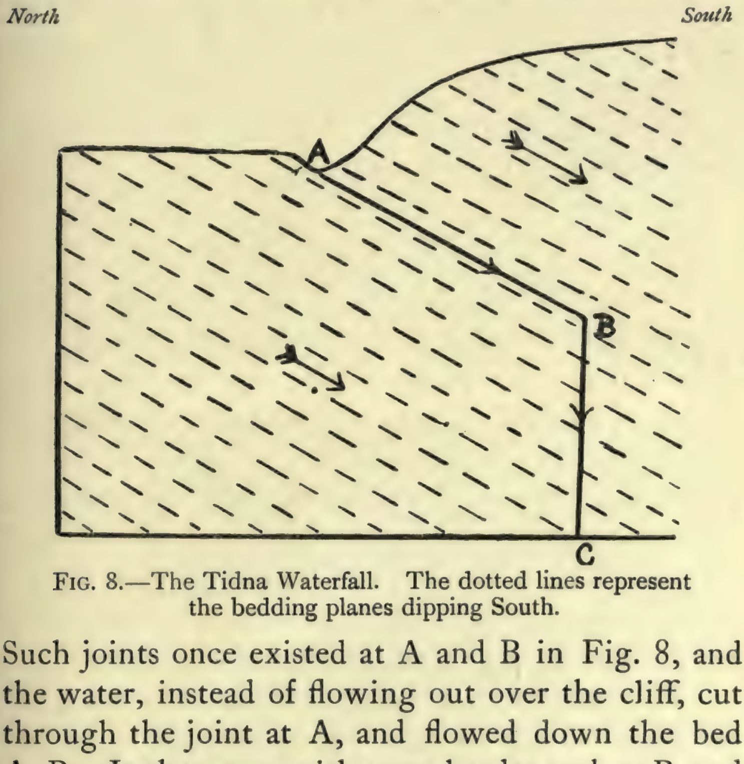

Fig. 8.—The Tidna Waterfall. The dotted lines represent the bedding planes dipping South.

Such joints once existed at A and B in Fig. 8, and the water, instead of flowing out over the cliff, cut through the joint at A, and flowed down the bed A–B. It then met with some harder rock at B, and cut its way seaward through a joint at that point.

On the north side of the Tidna Fall, there is a fine, deep bay, cut in the cliff, and much of the

northern wall of the seaward extremity of the Tidna valley has now been removed by the sea. At present, the sea is working parallel to the end of the stream for some little distance, and will perhaps one day cut off its termination at a point inland from the present fall.

Looking northward from this spot, some great walls or buttresses of eroded shales are seen projecting out into the sea from the cliff. Many such occur along this coast, and they may be particularly well studied to the South of Bude.

STANBURY MOUTH.

Leaving the Tidna, we climb its steep southern wall, and make our way to the end of Higher Sharpnose Point (about 250 feet above sea-level), from which a good view up and down the coast can be gained. We then proceed southward to Hippa Rock, the coast-line here presenting no features of special interest. At low tide, however, at Caunter Beach on the north side of Hippa Rock, the reefs on the shore show the structure of an anticline very clearly.

We next reach Stanbury Mouth, where a small stream flows on to the beach, through a canyon which has been to a great extent destroyed by landslips, and probably also by the making of the path down to the shore. The stream is not, however, quite at base-level, but there is no waterfall, only a

Plate XLIV

Fig. 1.—The canyon of the Abbey River, South of Hartland Point, looking up-stream from the beach.

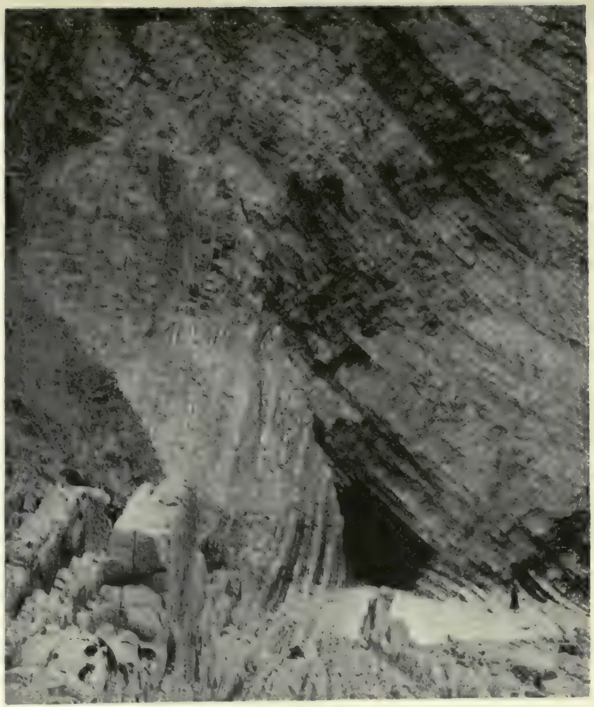

Fig. 2.—A sharp, anticlinal fold, eroded by the sea, North of Hartland Quay.

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few cascades, over steps or shelves of rock. The bed of the stream is largely choked with materials which have fallen from the old walls of the canyon. The brook is, however, interesting as an example of a late stage in the evolution of the mouth of a stream, at which a coastal fall once existed.

LOWER SHARPNOSE POINT.

Between Stanbury Mouth and Lower Sharpnose Point, the cliffs are much landslipped, and there are no good rock sections to be seen. Beds of calcareous nodules occur, however, on the north side of the Point, where at least one impure limestone band is also known. At the Point the beds are shales, tilted almost vertically. There are sometimes two very small streams, one on each side of a wall on the cliff above Holacombe Beach, on the north side of Lower Sharpnose Point, though in summer they are often quite dry. When they possess any water, they simply trickle down the landslipped face of the cliff.

The cliffs between Lower Sharpnose Point and the Coombe Valley are nearly 300 feet in height, but they do not present any remarkable features. The large stream (No. 61 on Map No. 1), almost a river, watering the Coombe Valley, is at base-level at its mouth. The walls of this valley are remarkable for their steepness, and are 400 feet in height on both the north and south sides.

SANDY MOUTH.

Between the Coombe Valley and Sandy Mouth, the cliffs are not particularly interesting, except that, South of Warren Gutter Beach, we find a sandy shore between high and low water marks, a most unusual event on this coast. These sands stretch to the South as far as Bude Harbour.

The small waterfall at Sandy Mouth (Plate XLV, Fig. 2) is worthy of examination. The main valley leading to the sea from Houndapit, along which the road passes, is at base-level at its mouth, and further its stream has now entirely disappeared. At its seaward termination, however, a tributary enters from the North, which is cut off, as a "hanging valley," from the main valley, the mouth of which has been considerably enlarged by sea erosion. Thus the tributary forms a small sheer fall, of about twelve feet in height, on to the beach (Plate XLV, Fig. 2). It is a strike fall over inclined beds dipping South at 60°. In 1909 a small trickle passed over the face of an inclined bed of sandstone, in the direction of the dip. This is seen in the photograph on Plate XLV, Fig. 2, on the right of the main fall, and, if the cliff section is not altered by sea erosion, the whole stream may one day take this direction.

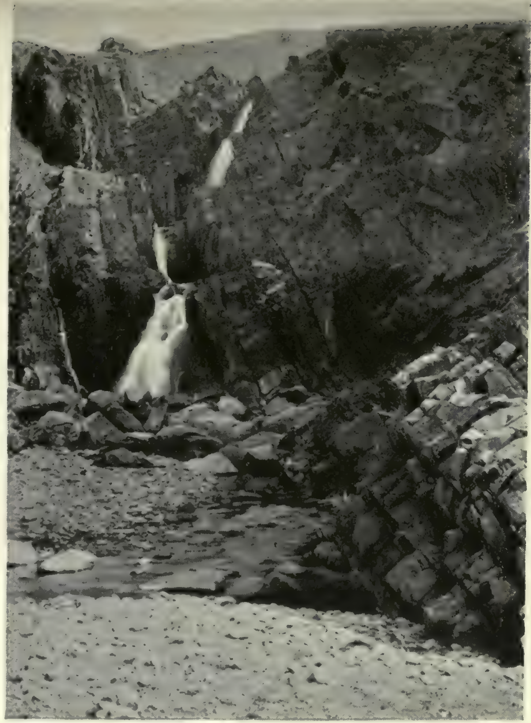

FIG. 1.—The Fall of Strawberry Water from the beach at Welcombe Mouth, looking East (Hartland District).

FIG. 2.—The Waterfall at Sandy Mouth, North of Bude, from the South (Hartland District).

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BUDE.

Between Sandy Mouth and Bude Harbour the cliffs are low, and the mouths of the streams are all at base-level. A walk along this strip of sandy shore at low tide should, however, on no account be omitted. The cliff sections show several very interesting anticlines, and, what is even more remarkable, synclines, in various stages of denudation. Between Sandy and Northcott Mouths there is a fine square-topped anticline, and, near the latter, another fine fold (Plate XLVI) in the base of which the sea has eaten out a large cave.

Between Northcott Mouth and Bude two good synclines occur. The one has an axis inclined towards the South, and its central beds have been destroyed by landslips. The other, nearer to Bude, and with an axis inclined to the North, is in a more perfect state of preservation (Plate II).

The existence of sand along this stretch of shore is chiefly due to the lowness of the cliffs in this region. The amount of material worked out of the cliffs by the sea is probably less here than elsewhere to the North or South, and such rock debris as occurs has been ground down by the sea to a greater degree than is the case where boulders are thickly strewn along the shore. Sand is thus a late stage in the evolution of a beach. Reefs and boulders do, however, occur

along this strip of coast, and the study of them offers good illustrations of how the sea works at, and erodes the rocks. Many of these boulders are to some degree protected by thick growths or colonies of Mussels and Acorn Barnacles, with the sandy tubes of the worm, *Sabellaria*.

This stretch of sandy shore presents a marked contrast to that immediately to the South of Bude Harbour, where the cliffs are high and the beaches exceedingly rocky. At Bude itself, hills of blown sand similar to those described at Woolacombe (p. 76) and Braunton Burrows (p. 83) occur, especially at the golf course and along the banks of the river Strat, the mouth of which is choked with sand. A considerable portion of the town is also built on sand.

Plate XLVI

A sea-eroded anticline, a short distance North of Northcott Mouth, near Bude (Hartland District).

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CHAPTER VI

DISTRICT VI.—THE BOSCASTLE DISTRICT

Our last District, from Bude to Boscastle, lies wholly in North-east Cornwall. It includes some very fine cliff scenery, but the cliffs are not quite so high, or so continuous, as in District V.

The northern portion of the district, from Bude to some distance South of Cambeak, consists of alternating sandstones and shales of Upper Carboniferous age. This stretch of coast, which includes nearly three-quarters of the whole, has cliffs of the Flat-topped variety. South of Rusey Beach, however, as far as Boscastle, the beds are of Lower Carboniferous age, and consist chiefly of shales, with subordinate beds of sandstone and Radiolarian cherts. The cliffs here are, for the most part, of the Hog's-back variety.

Headquarters.—The two chief centres are Bude at the northern, and Boscastle at the southern extremity of the district. Between the two there is no public accommodation, though lodgings may be obtained at some of the farms, and especially at Crackington Haven, which is situated on the coast at about two-thirds of the

distance from Bude to Boscastle. Crackington Haven is perhaps the most convenient spot from which to study this district, in conjunction with a few days' stay at Bude and Boscastle.

To reach Bude see p. 112. Boscastle is gained by the L. & S. W. Railway (Padstow line) from Exeter through Launceston to Camelford Station (nine miles from Boscastle), where buses meet the principal trains. Boscastle can also be reached from Bude by coach in summer (fifteen miles).

Crackington Haven is gained from Otterham Station (six miles), the station before Camelford on the L. & S. W. Railway, or by coach from Bude or Boscastle to Wainhouse Corner, whence the Haven is a walk or drive of rather more than three miles.

Directions.—The very interesting cliffs immediately to the South of Bude should be studied from the shore, which may be reached at Bude breakwater, and by several paths descending Efford Cliff, on the north, and Efford Ditch on the south side of the Beacon. There is also a well-known and much-used path to the beach, where the road from Bude to Widemouth reaches the cliff-line near Upton, just to the North of Phillips' Strand. The shore here to the North should certainly be explored, and, at favourable states of the tide, one can progress southward as far as Widemouth, passing on the way the Higher and Lower Longbeak.

Between the northern extremity of Widemouth Sand and Wanson Mouth, there is nothing to be gained by leaving the coast road, and the road should also be kept along Penhalt Cliff and past Foxhole Point to Millook Haven. From the Haven, the south side of Foxhole Point should certainly be examined from the shore, and to the South, the coast may be studied towards Saddle Rock and Broad Strand.

South of Millook Haven, we approach a long stretch of landslipped cliff, including the Dizzard Point. This may be descended at several places, one path leading to Cancleave Strand on the North side of Sharnhole Point, another descending Long Cliff to Chipman Strand, on the South of the Dizzard Point, while, with a little scrambling, it is possible to descend at Scrade Water Fall by

Plate XLVII

The marine erosion of Buttress-reefs in the cliffs to the South of Bude (Boscastle District).

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Stoneivy Rock. Thus the whole of this landslipped region may be easily examined from the beach.

Between Scrade and Crackington Haven one can descend beside the waterfall to Cleave Strand, and also at Thorn's Beach, but not, so far as the author can ascertain, between Castle and Pencannow Points.

From Crackington Haven, the southern flank of Pencannow Point may be examined at low tide, and it is also possible to study from the beach nearly the whole of the long northern side of Cambeak. Further South, via Trevigue, there is a good road down a landslipped cliff at the Strangles, by means of which the beach, between Cambeak and Voter Run, can be explored. Still further to the South, there is a path down Rusey Cliff to the beach of the same name, whereby we can explore northwards to Voter Run, and southwards at low water with the aid of a good deal of scrambling, for some little distance towards Boscastle.

Between Rusey Cliff and Boscastle it is only possible to descend to the shore at one point, Pentargon Fall. After examining Buckator and Gull Rock from the cliff path, it is best to bear inland to the cart road, which joins the main road to Boscastle about half-a-mile North of Pentargon. It is now almost impossible to get along the cliff from Buckator to Fire Beacon Point without trespassing, owing to the encroachment of agricultural land to the very edge of the cliff, and the impediments provided by the farmer.

From Pentargon, there is a path northward along Beeny Cliff, as far as Fire Beacon Point, and to the South, the cliffs to Boscastle may be traversed by several paths. Both these cliffs are of the Hog's-back type.

Maps.—One-inch Ordnance Survey : Sheet 322.

Six-inch Ordnance Survey : *Cornwall*—Sheets V., N.E. (does not include the town of Bude (see III., S.E.), but the coast from Efford Cliff to Lower Longbeak) ; V., S.E. (Widemouth and Wanson Mouth) ; V., S.W. (Foxhole Point and Millook Haven) ; VII., N.E. + VIII. N.W. (Dizzard, Pencannow Points and

Crackington Haven); VII., S.E. (Cambeak to Rusey Cliff); X., N.E. (Buckator, Pentargon and Boscastle).

It will be convenient to subdivide the Boscastle District into three sections: the Widemouth Section, from Bude to Millook Mouth; the Crackington Section, from Millook to Rusey and High Cliffs; and the Boscastle Section, from High Cliff to Boscastle. The coast scenery of each of these sections is dissimilar to its neighbour, though each is equally interesting in its own way.

THE WIDEMOUTH SECTION.

The cliffs immediately to the South of Bude offer a very fine series of sections. Unlike the coast to the North, the beach is strewn with boulders and there is a general absence of sand. The great buttress-reefs projecting from the cliff may be well seen from the cliff path, though they are best studied from the shore at low tide. The first of these occurs at Compass Point, and may be examined from the Storm Tower on the cliff, close to the breakwater. These buttress-reefs consist of a few beds of sandstone and shale, tilted almost vertical (about 80°) and at least one hundred feet in height.

At Efford Ditch, South of Efford Beacon, a fine section of bent and contorted rocks is seen in the cliff. Between the Ditch and Phillips' Strand,

Plate XLVIII

The great anticlinal fold in the cliffs to the South of Bude (Boscastle District).

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there are several high dykes of sandstone and shale, tilted at a very high angle, and projecting seaward from the cliff. One of these, near Phillips' Strand, is seen in the photograph on Plate XLVII. The rocks are here dipping southward, at about 70°.

A visit to the beach by the road down the cliff near Upton should on no account be omitted. Not only may the great buttress-reefs, above mentioned, be examined in detail, but one of the largest and most perfect anticlinal folds to be met with in the whole of North Devon and Cornwall occurs at a very short distance along the shore to the North of the path to the beach. This great anticline is seen on Plate XLVIII. It consists of four thick beds of sandstone, separated by thin beds of shale. The fold is an open one, *i. e.* the angle is wide, and not so sharp as in the case of the anticline at Tut's Hole, Cockington Head (p. 100, Plate III). It projects clear of the cliff.

To the South of the path to the beach, just at the next small promontory, a calcareous spring occurs a few feet above the base of the cliff. The spring has deposited a considerable amount of whitish, calcareous *tufa*, owing to the evaporation of the water, and the throwing down from solution of the calcium carbonate. The position of the spring, which might otherwise be easily overlooked, is readily located by this *tufa*. This is the only example of such a spring which has

been observed on the coast, in the whole area discussed in the present volume.

Near the spring, and also at Phillips' Point further South, good examples of folded and contorted rocks may be seen. Other examples of buttress-reefs, projecting seaward, composed of beds tilted at a high angle, may be seen at Church Races. The marine erosion of these buttresses offers an interesting study. Parts of them often become cut off, and form isolated "stacks," while others are degraded to reefs.

The low cliffs of the Longbeaks (Higher and Lower) present no special feature of interest, and their scenery resembles that met with further North.

WIDEMOUTH.

We now reach Widemouth, where the cliffs come to an end for a distance of about three-quarters of a mile. They slope gradually down from the North and South to nearly sea-level, and the country inland from the beach is only very gently inclined. The beach is sandy, as is usually the case along these coasts where the cliffs are non-existent, or have retreated inland owing to local upheaval. In fact, what we find at Widemouth corresponds closely to the state of affairs which originally existed at Bude, before the shore-line there was overwhelmed by blown sand.

These are the only real gaps in the cliff-line, apart from those cut by stream erosion, to be met with in the whole area described in this volume. Elsewhere, as at Braunton Burrows and Woolacombe, the cliffs have receded inland, owing to the recent elevation of the coast.

Where the cliffs begin to rise again towards Wanson Mouth, Black Rock is a conspicuous reef on the shore. It is formed of hard sandstones, dipping seaward, and corresponds in some respects to Blackchurch Rock at Mouthmill (p. 107, Plate XXVII).

The small streams, which enter the sea on the south side of Widemouth Sand and at Wanson Mouth, are at base-level, though some traces of a deep, senile canyon can still be seen at the latter.

MILLOOK MOUTH.

Penhalt Cliff and Foxhole Point are much landslipped and overgrown with vegetation, and there are no good sections to be seen until we reach Millook Haven. Here, however, a little to the North of the stream (which is at base-level) perhaps the finest section of contorted rocks to be found at any point along these coasts may be studied. A photograph of these contortions is seen on Plate IV. The rocks, which consist of thin beds of sandstone with shale partings, are bent in the form of a succession of **W**'s, placed on

their sides. These contortions should be compared with those seen at Broadbench Cove (p. 133, Plate XL).

THE CRACKINGTON SECTION.

South of Millook Haven, we have a long stretch of cliff-line, including the Dizzard Point, which is landslipped throughout to an extraordinary degree. It is the greatest extent of landslipped coast to be found in the whole area described here. One stream (No. 69 on Map No. 1) passes over the cliff at Sharnhole Point to the North of Bynorth Cliff, but there is no waterfall worth mentioning. The stream simply finds its way down irregularities in the broken surface of the cliff, and, at its termination, is split up into driblets by the unevenness of the ground, where it passes over the eroded section of the cliff, here only undercut by the sea for a few feet.

This landslipped cliff-line ends at Chipman Point, on the south side of which there is a very steep-sided valley, formed by the stream which we will here call Scrade Water (No. 70 on Map No. 1). The termination of this valley is still nearly 100 feet above sea-level, where the water passes over the cliff. The valley, especially in the steepness of its walls, which rise almost vertically for 300 feet on either side, recalls that

Plate XLIX

The marine erosion of contorted beds at the northern end of Cleave Strand, South of the Dizzard Point (Boscastle District).

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of the Heddon at Heddon's Mouth (p. 53), which is, however, at base-level. It also resembles the valley of Coxford Water (p. 156) a short distance to the South. The waterfall is worth studying from the beach. The cliff here is not vertical, but slopes seawards, and the rocks also dip in the same direction. The water flows along the dip of the beds, and is broken into cascades by the irregularities and broken nature of the strata over which it passes.

Stoneivy Rock, a few yards to the North of the fall, is a pretty and interesting little promontory, formed of contorted beds of thin sandstones and shales, the former being conspicuous by their abundant veining of quartz. Quartz veins are indeed very numerous and conspicuous in the beds throughout this section (see Plate XXII, Fig. 1).

Between Scrade Fall and Castle Point, the cliffs are landslipped, though to a less degree than in the Dizzard region. A small stream, which we may call Cleave Water (No. 71 on Map No. 1) passes over the cliff to Cleave Strand, but there is no waterfall. This brook, like that at Sharnhole Point, illustrates very clearly the influence of landslips on coastal falls. No doubt, in both cases, waterfalls may have once existed ; but when the cliff became landslipped, the streams were without power to cut a channel, and they now wander

down the sloping surface of the cliff, their course being determined simply by its irregularities.

There are some excellent, though rather broken, contortions (Plate XLIX) to be seen at the northern end of Cleave Strand, and also some good remnants of anticlinal folds (Fig. 10, p. 193).

COXFORD WATER.

Before we reach Crackington Haven, we come to the very interesting valley of Coxford Water (No. 72 on Map No. 1), which ends between Castle and Pencannow Points. Its walls are very steep-sided, like those of Scrade Water, to the North. Here, however, the sea is directly attacking not only the mouth of the stream, but a considerable stretch of its northern wall, the highest part of which has already disappeared. Curiously enough, this wall (Plate L) at its western termination projects seawards for some little distance beyond the stream, and beyond the bottom of the valley. The sea has demolished the corresponding wall on the south side, at the end of the stream. The brook ends in a sea-cut gully. It is here still some thirty feet or more above sea-level, and there is a picturesque waterfall, known as Aller Shoot, at its mouth.

The photograph on Plate L shows the fall at low tide, and the seaward projection of the northern wall, with the sea working parallel to the valley

Plate L

The Fall of Coxford Water at Aller Shoot, near Crackington Haven, at low tide, from the cliff, looking North (Boscastle District).

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behind it. At high tide, the fall ends in the sea. It is broken into leaps by irregularities in the sloping section of the cliff.

It is worth while climbing the extremity of the northern wall of Coxford Water to see the folded grits in the cliff-face, on the opposite side of Orchard Strand.

CRACKINGTON HAVEN.

At Crackington Haven, the sea has greatly enlarged and widened the mouth of the valley between Pencannow Point and Cambeak. The stream entering the sea here is at base-level. Pencannow Point has typical Hog's-back cliffs on either side, probably owing to the fact that it is the end of a high ridge, separating two nearly parallel, very deep, river valleys, situated only a short distance apart. There are no good folds to be seen at Crackington Haven, though some highly inclined rocks occur. The northern face of Cambeak is, however, remarkable. Between Tremoutha Ball and the Point, there are three small parallel valleys, of which the two to the East generally contain small streams. That nearest the Point (Cam Draught) is usually dry, though traces of a waterfall exist here. Of the other streams, the central one usually contains the most water. It flows over a broken undercliff, and ends in a quite sheer fall about fourteen feet in height.

On the south side of Cambeak, as far as High and Rusey Cliffs, the cliff-line is much landslipped, especially the lower part of the cliffs. There are several interesting "stacks" to be seen here, completely cut out of the cliff by sea erosion, and remaining as isolated masses of rock between tide limits. Samphire Rock, on the Strangles, is one of these, and another, of even larger size, occurs on the north side of Voter Run. But perhaps the most interesting is Northern Door, North of Samphire Rock. The sea here has cut out a small promontory by working laterally and constricting it off from the land. Where the constriction occurs, the sea has cut right through the promontory; but the higher beds, removed from the full force of the waves, remain as a roof to the cave.

THE BOSCASTLE SECTION.

The last Section of this District, beginning at Rusey Cliff and ending at Boscastle Harbour, is a short one. To the inexperienced eye, there may appear to be but little or no change in the cliffs, or in the rocks, as we pass southward from Rusey Cliff. As a matter of fact, we are here upon beds of Lower, and not Upper, Carboniferous age. The junction between these two systems occurs in the landslipped cliff a short distance North of Buckator and East Delabole Works, practically at the point

where the by-road to Beeny (branching off to the West from the road from Trevigue to Boscastle) approaches nearest to the cliff. The line of junction was first located on the coast by the author in 1908. It was examined shortly afterwards by the officers of the Geological Survey, who reported that the actual junction was a thrust plane. Thus, unfortunately, this section throws very little light on the original stratigraphical relationships of the Upper and Lower Carboniferous in North Cornwall. This is the more to be regretted since, on the northern side of the basin in North Devon, the corresponding section is not exposed on the coast.

While the Upper Carboniferous rocks (Upper Culm Measures) of North Devon and Cornwall consist of a monotonous succession of sandstones and shales, the Lower Carboniferous rocks (Lower Culm Measures) in this part of Cornwall are chiefly black shales, with subordinate bands of sandstone, and occasional deposits of Radiolarian cherts. A marked abundance of thick quartz veins, sometimes four feet across, is very characteristic of the Lower Carboniferous sequence, as here developed. So much so that, passing along the countryside, one can recognize the fact that one is traversing these rocks by the conspicuous veining of the sections exposed in the roadside, or of the slabs used to build up the rough boundary walls.

There is also a change in the nature of the cliff scenery in the area occupied by the Lower Carboniferous. Flat-topped cliffs prevail up to Rusey Beach, but beyond, especially in Beeny and Penally Cliffs, we have a return to the Hog's-back type, with which we are so familiar in North Devon, North of Barnstaple Bar. These cliffs, it is true, are not nearly so pronounced as regard height, or the steepness of the seaward slope, as those between Porlock and Lynton, or between Heddon's Mouth and Combe Martin ; yet they unmistakably conform to the same type.

We notice another change in the somewhat more indented nature of the coast-line. The sea is here cutting many narrow and deep clefts into the land.

PENTARGON.

Beeny Cliff and Buckator are landslipped, and not of special interest, except as regards the large, almost square-topped, picturesque "stack," known as Gull Rock, which has been cut out of the southern flank of Buckator by sea erosion. It is easy in this case to see how the sea works by driving a cleft through a little promontory, and this is of importance as illustrating the origin of other stacks further South, at Boscastle Harbour and towards Tintagel.

Opposite Gull Rock there is a small marshy

stream (not indicated on the six-inch map), forming a very small fall over the cliffs, which are here of considerable height. It is not possible, however, to see the actual fall, since the shore cannot be reached.

At Fire Beacon Point, there is a conspicuous ridge of Radiolarian chert, a siliceous rock largely made up of the "tests" of Radiolarians. The bed is over eighty feet in thickness. Similar cherts occur at Coddon Hill, near Barnstaple, in North Devon, and at other inland localities, both in Devon and Cornwall.

The next point of interest is Pentargon, a deep sea-cut gully at the head of which there is a fine fall, especially when the stream is in flood. The upper portion is a sheer fall in two or three leaps, but towards the bottom the water flows in the direction of the dip of the beds (which is here to the northward) as a kind of gutter fall (see p. 226). The face of the cliff, here 150 feet in height, has been eroded entirely by the sea, and the erosion is apparently so rapid that the stream has little opportunity for cutting back into its bed. This is the only waterfall on Lower Carboniferous rocks on the whole coast-line.

Between Pentargon and Boscastle, the cliff walk affords excellent opportunities for examining the sea erosion of the soft Lower Carboniferous shales, forming the Hog's-back cliffs. The succession of

deep gullies, cut in the western face of Beeny Cliff, and at Pentargon Sealhole, and Little Pentargon, show various stages in the attack on the land, and the work of the sea in this region.

BOSCASTLE.

The Valency at Boscastle is a large stream at base-level at its mouth. Further, the coast here has recently been depressed, and thus the sea has drowned the river mouth. The photograph on Plate LI shows the entrance to the harbour at low tide, the only period when the sea does not fill the mouth of the stream.

The folded beds, with conspicuous quartz veins, on the north side of the river, show many signs of sea erosion. This drowned river mouth corresponds to Watermouth in the Ilfracombe District (p. 60, Plate XI).

The "stack" which is so prominent, just beyond the mouth of the harbour, has been cut off from Penally Point in the same way that Gull Rock has been isolated from Buckator (p. 160). Owing to the sinking of the coast, this stack is now washed by the sea at all states of the tide, and the channel between it and the land has naturally been greatly widened. Further, the sea is also at work cutting off another portion of Penally Point, which has already a waist-like constriction, between the Point and the Hill of the same name, just beyond

Plate LI

Boscastle Harbour, at low tide (Boscastle District).

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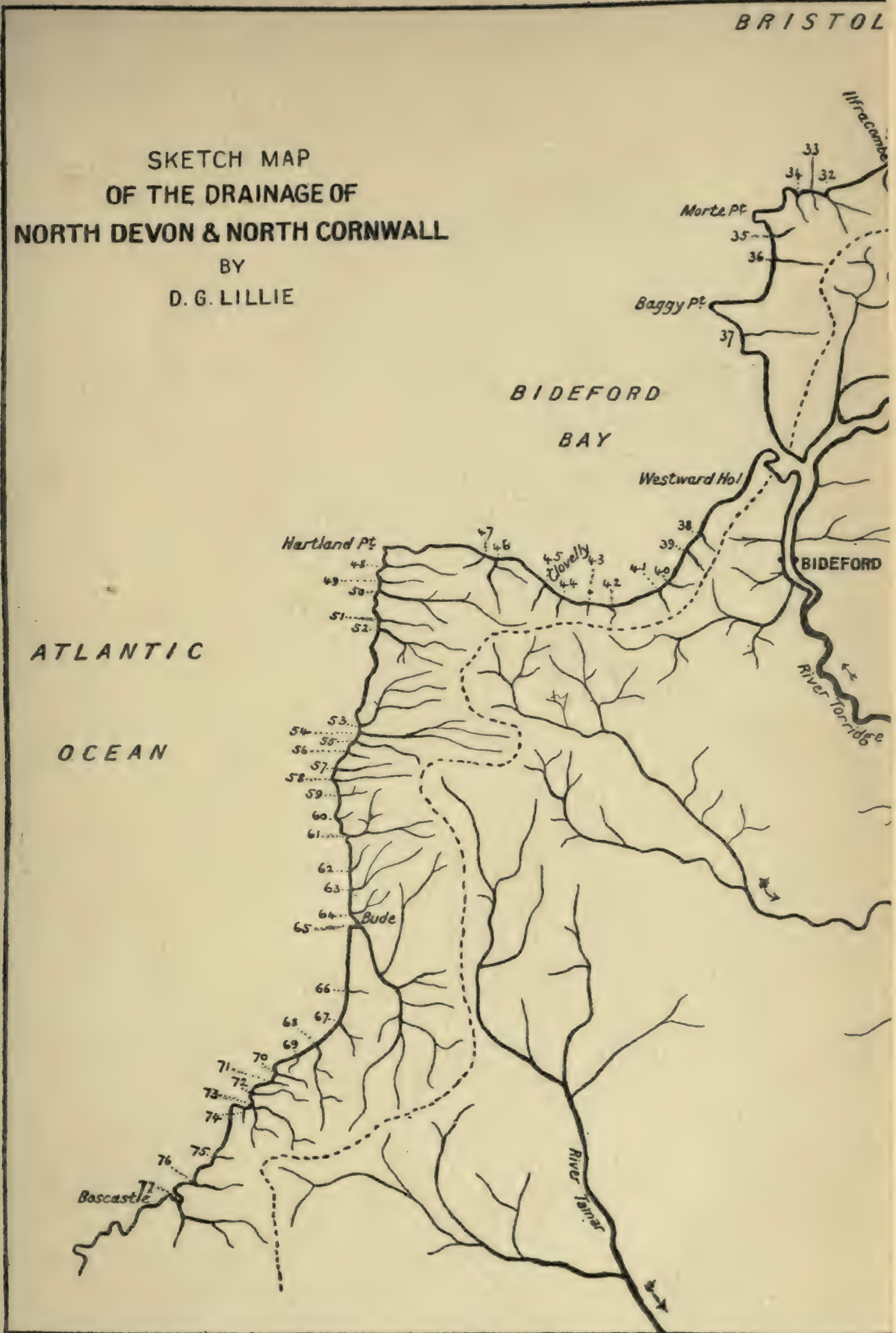
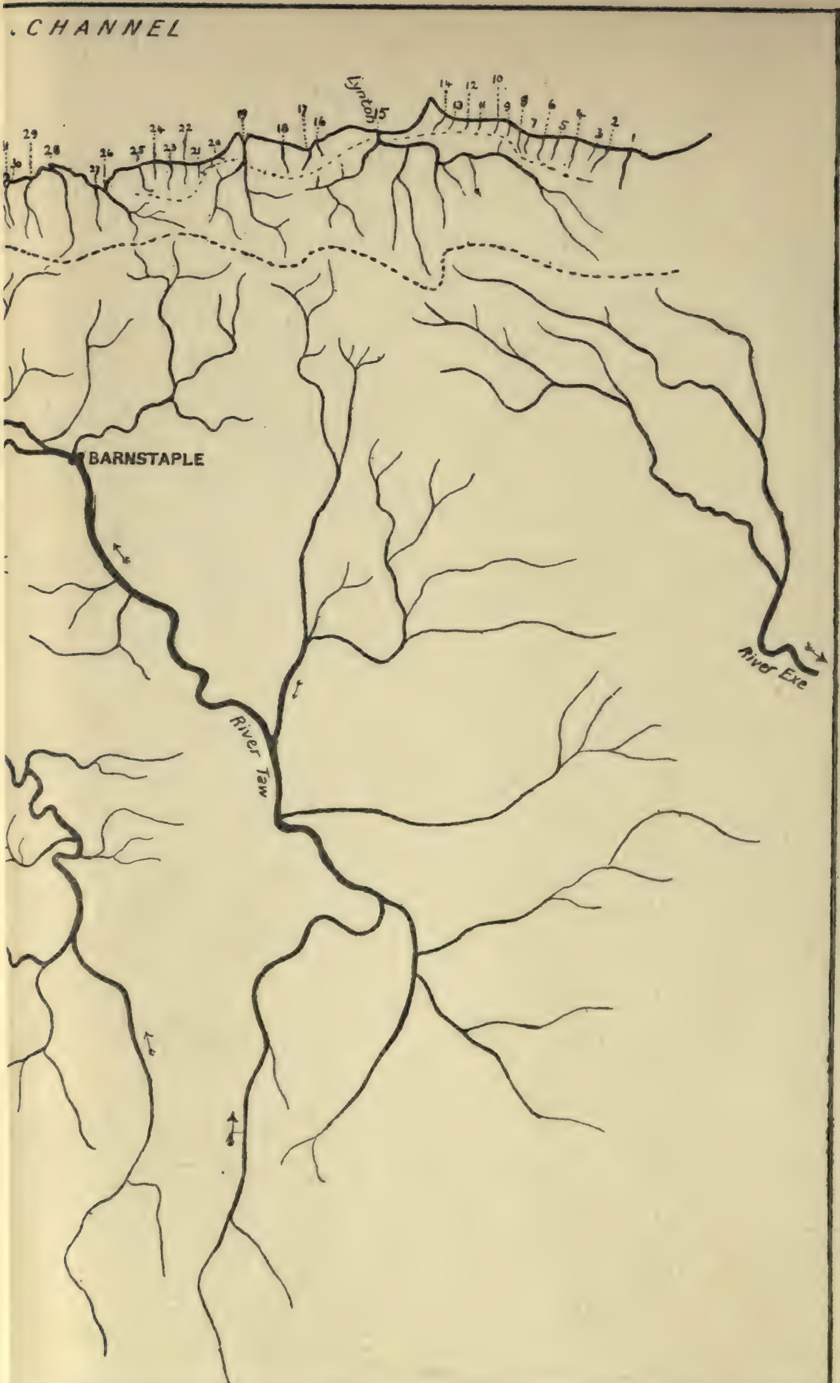
the right-hand side of the photograph on Plate LI.

A very short distance to the South of Boscastle the Lower Carboniferous sequence ends and the more ancient Devonian rocks appear. These Devonian rocks occupy a very large part of South Cornwall and South Devon. We shall not deal with this coast-line here, since the area with which we are concerned in the present volume is that occupied by rocks of Carboniferous age, and by the North Devon Devonian series. So far as the author is aware, coastal waterfalls are unknown to the South of Boscastle, and the general character of the coast of West and South Cornwall is, in several important respects, dissimilar to that described in the present volume.



SKETCH MAP
OF THE DRAINAGE OF
NORTH DEVON & NORTH CORNWALL
BY
D. G. LILLIE
BRISTOL
Morte Pt
Baggy Pt
BIDEFORD
BAY
Westward Ho!
BIDEFORD
Hartland Pt
Clovelly
ATLANTIC
OCEAN
River Torridge
Bude
Boscastle
River Tamar

Map No.



I.

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PART II

THE SPECIAL FEATURES OF GEOLOGICAL INTEREST OF THE NORTH DEVON AND CORNISH COASTS

CHAPTER VII

THE MARINE EROSION OF FOLDED ROCKS

In the present chapter we will pass to a special study of the work of the sea in relation to coast and cliff scenery. These matters have been much neglected in recent years, when attention has been chiefly devoted to means of preventing the encroachment of the sea on the land. Nor would it appear that a detailed study of marine erosion has ever attracted the observation which it merits in this country. We have been content to accept, as embodying the whole matter, such text-book platitudes as that the hard rocks stand out as points, and the soft rocks, being more easily eroded by the sea, form the bays between them; or that the greatest erosive power of the sea is in times of storm; or again, that it is rain and frost, rather than the waves, which cause the chief damage to cliffs.

COAST EROSION.

It is no doubt a good general rule that the origin of the headlands of our coasts is to be sought

for first in the hardness of the rocks of which they are formed, as contrasted with those more easily cut into bays. In districts where hard and soft rocks alternate fairly regularly, as in Pembrokeshire and in some parts of Ireland, it is easy to trace the origin of the chief features of the coast. But in many cases no such alternation exists. The rocks forming the coast-line may be uniform in respect to hardness for many miles. What in such cases is the origin of the points and bays?

Let us take some simple illustrations from North Devon. The rocks forming the coast from Porlock to the Foreland, a little East of Lynmouth, consist of one lithological type, the Foreland Grits. How are we to account for the existence of the very marked prominence at the Foreland and the almost complete absence of any points and bays to the East, until Porlock is reached? The explanation has, as we shall see, little or nothing to do with the hardness or softness of the rocks. It is to be traced, on our view, to the topographical features of the land itself, prior to erosion. The same is true of Hartland Point, which, as we have pointed out (p. 115), is really a right-angle turn in the direction of the watershed. In both these examples, the sea is attacking an elevated watershed. In the case of the Foreland (see p. 39), we see the remains, the stump so to speak, of a subsidiary elevated ridge running out to the North, at

right angles to the main coastal watershed. In the case of Hartland Point, the erosion simply follows the change in the direction of the watershed. The rocks on both sides of the Point, for many miles to the East and South, are identical in hardness and other physical characters.

THE MAIN TOPOGRAPHICAL FEATURES OF THE COAST-LINE.

We will now study the origin of the chief promontories and bays of the coast-line with which we are concerned in the present volume. If the outline of the North Devon and Cornish coasts be examined on a 1-inch or some larger scale map, it will be found that the following are the chief topographical features. From Porlock to Morte Point, the coast bordering the Bristol Channel is practically straight, or with only a slight trend to the West. The Foreland is the sole prominence. Between Morte and Baggy Points, there is a small bay (Morte Bay). Next, between Baggy and Hartland Points, there is a large curve known as Bideford or Barnstaple Bay. South of Hartland Point, the coast trends straight to the South for many miles, to some distance beyond Bude, Higher Sharpnose Point, though not of any real importance as a coastal feature, being the most conspicuous prominence. Bude Bay hardly exists except in name. Between Wide-

mouth and Boscastle, the outline of the coast becomes more irregular, and as a whole is convex to the Atlantic. But nowhere is this coast so irregular or deeply indented as further South in Cornwall, especially near Padstow and Newquay.

Let us now consider the headlands. The Foreland Point has already been explained. Bull Point (p. 73) is, like Hartland Point, a right-angle turn in the coast in conformity with the change of direction of the watershed (see Map No. 1). Morte Point, like the Foreland, is the remains of an old ridge of high ground, projecting westward at right angles to the main watershed, though, in this case, the promontory has been worn very low, especially near the end of the Point, by atmospheric denudation. The rocks forming Morte Point, like those of Rockham Bay to the North, and part of Morte Bay to the South, consist entirely of slates. The slates forming the promontory have not been shown to be in any way more resistant than those of the bays either side. Further Bull Point, which is entirely dissimilar in its physiognomy to Morte Point, is also built up of the same slate series.

The long nose of Baggy Point is likewise a westwardly projecting ridge of high ground, or in other words the remains of a secondary watershed. It consists of three different series of Devonian rocks (the Pickwell Down, Baggy and Pilton Beds),

including both sandstones, shales and slates. Yet there is no indication that the lithological character of the beds has any particular influence on the shape of the promontory. Its outline is characteristic of that of all the real points along this coast, omitting right-angle turns such as Hartland and Bull Points. The long northern side is almost straight, while the southern flank is curved, and concave towards the sea. Morte Point and the western flank of the Foreland show similar curves, and Saunton Down End, which is another east and west ridge situated a little further South, is a minor promontory with similar features.

Thus, of the five major Points of this coast-line, two are right-angle turns, in conformity with the direction of the watershed, and three are the relics or stumps of subsidiary watersheds, roughly at right angles to the main watershed.

In none of these cases is it apparent that the character or hardness of the rocks has any special significance in explaining the existence of these promontories. On the other hand, it is obvious that the sea is cutting back the land in conformity with the pre-existing sculpturing of the country, due to long-continued atmospheric denudation.

This conclusion, which seems clearly established so far as this coast is concerned, is of great importance, and must be borne in mind when we come to discuss the origin of the chief Bays. Of

these there are only two of major importance, Mortehoe Bay, between Mortehoe and Baggy Points, and the great Bideford (or Barnstaple) Bay, between Baggy and Hartland Points. These are probably the results of complex factors differing in each instance. In the case of Morte Bay, matters are complicated by the uplift, which has taken place within comparatively recent times (see pp. 77 and 79) of which the Raised Beach of Baggy Point, and the retreat of the old cliff-line inland at Woolacombe Sands, afford convincing evidence. Perhaps, however, this so-called bay is only a short stretch of coast, nearly straight and conforming with the general trend of the main watershed, enclosed between the relics of the two secondary watersheds known as Morte and Baggy Points.

Whether or no this may prove to be the explanation of Morte Bay, there is no doubt that Bideford Bay presents a much more difficult study, and one which demands further attention before we can hope to understand its present physiognomy. It is a very old depression on the coast, which follows closely the general trend of the main watershed (see Map No. 1). It is complicated by the estuary of the Torridge and the Taw, and by the fact that the northern portion of the bay has been raised by several feet comparatively recently (see p. 96). In shape it conforms somewhat closely to Morte Bay, the southern portion of the curve being

flattened. This is probably due to the fact that when the tides and waves, which on this coast come up from the South-west, rush past Hartland Point, they tend to hug the leeward flank of the headland. The scouring out of the northern flanks of the headlands, so that their outline becomes nearly straight, is characteristic of the majority of the promontories, both large and small, along this coast. The same action of the waves is often very clearly seen on the northern side of the large buttress-reefs of shales (p. 142) met with in the Hartland District.

We shall not attempt a fuller discussion of the difficult question of the origin of Bideford Bay here, but we may point out that at least some of its features were determined by the original physiognomy of the land surface, which for long periods has here been slowly removed by marine erosion.

THE MINOR TOPOGRAPHICAL FEATURES OF THE COAST-LINE.

So far we have discussed only the major features of the Devonshire coast-line, and we will now pass on to study some of the headlands and bays of minor importance. However straight a stretch of coast may appear to be on a small-scale map, when we come to examine the coast-line itself, or a large-scale map, of 6 or 25 inches to the mile, we find

that its outline consists of a chain of small promontories, with little bays between them. This is the case even where the section of the coast examined consists of one type of rock, presumably of equal hardness throughout. The size and number of the points and bays varies, however, with the geological structure. They are most numerous between Combe Martin and Woolacombe, where a series of slate rocks forms the coast-line. They are least in evidence between Porlock and the Foreland (Foreland Grits) but rather more so between Heddon's Mouth and Combe Martin (Hangman Grits) and between Westward Ho ! and Hartland Point, and to the South nearly as far as Boscastle (Upper Carboniferous sandstones and shales).

The origin of these promontories and bays depends on a number of complex factors, which may vary in different places. The relative hardness or softness of the rocks may play a part, or the existence of some plane of weakness in the cliff section, in the past or even at the present time, may have been the chief determining factor. Again the physiographic features of the land may have a profound influence. For instance, the mouth of a stream entering the sea, or a region of low-lying cliff-line, often tends to initiate a bay. In Devonshire and Cornwall, as we shall point out shortly, the results of marine erosion are complicated by the fact that the rocks are highly folded, and the scenic

effects produced by their erosion depend on a number of circumstances.

At the same time one can actually see, along this coast-line, all stages in the initiation of a promontory and a bay. This study is best undertaken in those districts where the coast is formed of one type of rock, of approximately uniform hardness. Both sections of District II (especially the Ilfracombe beds of the Watermouth Section) and the Morte slates of the Woolacombe Section, as well as the Lower Carboniferous shales of the Boscastle Section of District VI, offer perhaps the best ground for such a study. We find that here the course of events is essentially as follows. The sea, in attacking a cliff-face, searches for some place of weakness, such as a large master joint or fault, or, in the case of a slate series, a plane of cleavage. Or perhaps a bed somewhat softer and more easily eroded presents itself. Whatever the plane of weakness may be, the sea takes advantage of it, and tends to cut a gully in the cliff. The form of the enlarged gully varies with the nature of the rock and other circumstances. It is often V-shaped, while in the case of a slate series, it becomes more like a U with parallel sides. As the gully increases in size it often alters in form, and becomes ◡-shaped, with a rounded curve. The sea tends to widen the gully by cutting out the beds of its lateral walls.

Such are the chief elementary forms of the bays. As erosion continues they increase in depth, and especially in breadth. The promontories, between a series of such gullies or bays, are often broad at first, but they become more pointed as the bay increases in width, at the expense of material removed by the sea from the flanks of the headlands. Finally the points may be completely worn away and thus merge into the bay.

On the other hand, all the minor points along this coast do not arise in this way. Some are no doubt formed of beds of rock, somewhat harder than those of the walls of the bays on their flanks. Others, again, are due to the differential erosion of high as compared with low land. The study of the origin of the minor points and bays of this coast-line is thus a difficult and complicated matter, and, as very little attention has hitherto been directed to it, we have still much to learn on the subject. Woody Bay, in District I, for instance, is a curve which is not easy to explain. There are, however, some instances in which the origin of the point seems to be evident, and to these we will now turn.

Cases in which the Points appear to consist of harder or more resistant rocks than the bays on their flanks are few. Cockington Head and Windbury Point in District IV, Blackstone Point

in District II, and possibly the Higher and Lower Longbeaks in District VI, are perhaps examples. The erosion of river mouths into bays is well seen at many localities along the coast. Wringcliff Bay, near Lynton, marks the former termination of the stream which once flowed through the Valley of Rocks, and which was considerably above base-level at its mouth, as it still is. The sea here has cut deeply into the cliff at its lowest point, which corresponds with the floor of the valley, cf. Aller Shoot in District VI (p. 156). At Lee Mouth, a little further to the West, the stream is nearer base-level, though it has not as yet reached that stage. The sea has, however, enlarged the former mouth of the stream, and cut out Lee Bay, originating Duty and Crock Points. A similar case occurs in District VI, at Crackington Haven, where the widening of the stream's mouth has given rise to Pencannow Point and Cambeak on either side. Croyde Bay, in District III, between Baggy Point and Saunton Down End, is another example. A still wider bay occurs at Combe Martin, between Hangman Point and Widemouth Head, which appears, in part at least, to be of similar origin.

Sometimes one of the walls of a river valley projects seawards as a point. This is the case, among several examples, at Highveer Point at Heddon's Mouth, and Higher Sharpnose Point

(p. 140), while Longpeak (p. 133) in District V is the wall of a lateral valley of Milford Water.

It is thus clear that many of the minor topographical features of this coast-line, like the major, are initiated in accordance with the form and peculiarities of the land surface which is being attacked by the sea.

CLIFF EROSION.

We turn next to a more special study of the attack of the sea on the cliffs of this coast-line. The work of the sea is to eat away the land, and to reduce all elevations above sea-level to a nearly plane surface beneath its waters. Thus the denudation of the land implies also the deposition on the floor of the ocean of the materials won from the assault on the coast. We will first of all consider the manner of denudation of the cliffs, reserving, for the moment, a consideration of the work of the sea on the beach and shore.

Alterations in the position or features of the cliff-face are always in progress, though for the most part at a very slow rate. They are directly or indirectly the result of sea erosion, though this factor is very rarely, if ever, at work alone. Usually the atmospheric weathering of the cliff aids the sea in its task, often to a very considerable extent. Where the cliffs are not undermined, and

the sea is performing little active erosion at their base, owing, perhaps, to the existence of a pebble ridge protecting the foot, or to some other cause, the atmospheric weathering of the cliffs may be the chief agent in their destruction. At the same time, we must remember that, even here, marine erosion is indirectly responsible. For the existence of a cliff section, which originated from sea erosion, is the chief cause of the instability, under the influence of atmospheric weathering, of the land bordering the ocean.

By atmospheric weathering, we here imply the effects of water percolating through the mass of the cliff, and derived from rain falling on the land at the top of the cliff. This water, as it penetrates the soil, subsoil, and unaltered rock, tends to wash out, or in some cases to dissolve, particles of the solid substance of the cliff, through which it makes its way. In this manner the joints and other planes of weakness are widened. The greatest damage, however, to the internal structure of the cliff is done in times of frost. As the water held in the rock freezes and becomes ice, it expands, and so forces apart the layers of rock between which it is contained, and thus the internal substance of the cliff is shattered. After a prolonged period, during which it has been subjected to frequent frosts, while parts of the rock have been washed away or dissolved out by

percolating water, the cliff-face is no longer a solid, compact mass of masonry, but resembles a wall of bricks, built without any binding substance such as mortar. The cohesion of the whole is greatly lessened, and, if the base of the cliff receives repeated heavy blows from waves, the whole face tends to totter, and eventually to fall. Thus a considerable thickness of the whole cliff-face may be thrown seaward, especially if the cliff is undercut at the base by sea erosion, in the manner which we shall explain shortly.

In some cases, however, usually under somewhat special conditions, larger areas of the cliff extending further inland may move bodily seaward. This phenomenon is termed a *landslip*. A landslip is a slide, rather than a fall towards the sea. Here also, just as when the veneer, so to speak, of the cliff-face is brought down, the result is largely due to the same atmospheric agency which is at work loosening the internal structure, and thus preparing for the final result.

We now come to study more especially the work of the sea. We can distinguish between two destructive forces, the action of the waves and of water-carried debris.

The subject of sea waves is of a complex and detailed nature, and we will only outline here some of the simpler and more important matters in this connection. There are various causes which

give rise to the movements of the waters of the ocean. Of these the chief are, the rotation of the earth on its axis, the existence of differences in temperature and barometric pressure at different points on the oceans, and the variation in the salinities of its waters. The movements result in waves and currents. Waves are due primarily to wind, though both currents and tides, under certain circumstances, increase their magnitude. For instance, the largest and most powerful waves, in time of storm, are those near high tide, when the wind is blowing directly on to the land, and especially when the wind has changed before high tide, from a direction along the coast with the tide, to one directly on land.

Waves, however, often break on a coast in perfectly calm weather. These are known as the *ground swell*, and are not due to the presence of wind in the neighbourhood of the shores on which they break. They have originated from undulations of the ocean, set up under the influence of gales or other strong winds, in some distant region, and since the undulations travel faster than the wind they soon spread beyond the limits of the storm, and may eventually end on some distant shore, in a region of calm.

Let us now consider the effect of the force of the waves alone on a cliff, under varying circumstances. We will suppose that near the high-

water mark of neap tides (when the difference in height between high and low water marks is least) the waves have direct access to the base of the cliff. Naturally the effect depends, to some extent, on the state of the tide. It is greatest at high water of spring tides, and least at low water of the same tides. In Bideford Bay, the difference between these two marks is about twenty-six feet. Between these two states there is every gradation during the month, day by day, and tide by tide. In times of calm, if there is no appreciable swell, the rising tide washes the cliffs gently, and if the rocks are fairly hard and the build of the cliff fairly stable (see p. 190), and its internal structure is not loosened, the effect of the waves alone is very small. They gently lap the base of the cliff, perhaps tending to smooth and polish it, and in some cases causing possibly some slight chemical alteration in the rocks after a prolonged period of immersion in sea water. If there is a ground swell, we get much the same effect as if a stiff breeze were blowing off the coast, and in times of storm, at high water and with an on-shore wind, this effect is at its maximum. The waves now, instead of simply lapping the base of the cliff, direct heavy blows against its face. These blows take place in three directions, one perpendicular to the cliff-face, another upwards, and another downwards. The effect of the horizontal force is like that of a battering-ram, urged

against some obstruction. It tends to shake, to loosen, and to drive inwards the lower part of the cliff. The result is that, if the internal structure of the cliff has been loosened by atmospheric weathering, the face tends to topple seawards. The deflected downward and upward blows also tend to shake and loosen still further the foundations and the rocks higher up the cliff. In times of storm, the force of the wave may be equivalent to three to four tons per square foot. It has been stated that the pressure of an Atlantic wave off the western coast of Britain is about 600 lb. in summer, and 2,000 lb. in winter, per square foot. Thus the blows directed on to the cliff-face may be very considerable.

The effect of waves on a cliff is, however, more than that of pressure pure and simple. It must be remembered that a cliff-face is never a plain, smooth, unbroken surface. It is usually very irregular in detail, the cracks and cavities being numerous. One of the important effects produced by the breaking of the waves is suddenly to compress and contract the air contained in the joints, cracks, and other irregularities of the cliff-face, and when the wave retreats the air as suddenly expands again. This process, many times repeated, tends to shatter the rocks, to enlarge the cracks, and to disintegrate the cliff-face, little by little. Here again we have another cause tending to alter the solidity and stability of the cliff.

But the weight of water thrown against the cliff, and the compression of the air in the cracks and other irregularities, are often of minor importance, as regards cliff erosion, compared with the damage done by the beach material hurled at the cliff-face by the sea. As a wave travels up a shore it gathers up and pushes before it a considerable quantity of the rocky debris derived from the wear and tear of the coast. In times of storm, not only sand and shingle, but huge pebbles or boulders are added to the weight of the blows delivered by the waves at the foot of the cliff, and thus the efficacy of the battering-ram is increased. But what is more important is that this transported beach material scours the rocks, breaks off the projecting angles, and smooths, polishes, and grinds down the surface of the cliff-face. If it meets with comparatively soft beds, it tends to cut them out and to leave the harder beds above overhanging, as we shall see presently. Thus the cliff is often undercut in this way, and its stability is thereby decreased. These transported materials are the tools of the sea, and tools of its own making.

The attack of the sea on a cliff section varies in its effectiveness according to various circumstances. The front of the cliff may be protected by a high pebble ridge (Plates LVII and XXIV), which, except in periods of severe storm, near the time of high water, prevents the sea from working

directly at the cliff section. The nature of the section, the hardness and character of the rocks, the degree of folding, all have, as we shall see, a profound influence on the life and features of the cliff, and on the rate at which it is cut back. The coast-line of North Devon and Cornwall offers excellent ground for a study of the way the sea eats into the land under many different circumstances. The factors which control the final result are often very complicated, and to this is due the great variety in the character of the cliff scenery met with along this coast. To attempt to explain the origin even of some of the typical features is a difficult matter, to which little study has as yet been directed. There are, however, some simple cases to which attention may be called here.

THE TYPE OF CLIFF SECTION.

One factor of importance is the type of cliff section. In the case of the Hog's-back cliffs, the portion of the seaward slope, which has been removed by the sea, is usually only a small fraction of the whole. This type of cliff (see Text-fig. 4, p. 15) is naturally stable. The rain falling on the slope tends to run down it, rather than to sink in and to percolate the rock. This is probably one reason why this type of cliff appears to be less liable to landslips. In the case of a Flat-topped cliff, if the section is nearly vertical, and the rock has been

loosened by weathering, the whole height of the outer face will tend to fall seaward, under the action of the waves at its base. The immediate result is that a "scree" of debris is heaped on the shore, between the sea and the cliff, and this, while it lasts, will tend to protect the cliff. Eventually it will all be removed, and a new face of rock exposed to the action of the waves. If, however, the land bordering the sea is rendered unstable by atmospheric weathering for a considerable distance inland, and the cliff is severely undercut at the base, or the rocks dip seawards, then large masses of the cliff will tend to sink and slide seaward, and we have a landslip. Such movements are particularly likely to occur where soft rocks, such as shales, dipping seawards, form the base of the cliff. The harder rocks tend to slip over the softer. The landslip, however, differs very markedly from a scree. The latter is a fall, while a landslip is a slide forward and downwards of a large mass, otherwise little altered in its scenic features except that its summit is usually broken into step-like terraces, owing to the development of cracks parallel to the shore, and the sinking of each terrace a little lower than that next it on the landward side. Such landslips are wonderfully permanent, and the sea may erode their faces in the same way as it works at a nearly vertical compact cliff.

Plate LII

A thin bed of shales, between sandstones, being cut out by the sea. The cutting boulders are seen in position as left by the tide. West of Clovelly.

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THE RELATIVE HARDNESS AND SOFTNESS OF THE ROCKS.

The effect of sea erosion may depend primarily on the relative hardness or softness of the succeeding beds of the cliff section. This is a factor in cliff erosion which may be studied to great advantage in Districts IV and V, and part of District VI, where the rocks consist of alternating beds of sandstone and shale of various thicknesses. In other districts the rocks are, for the most part, of uniform hardness, as in the case of the coasts formed by the Foreland Grits (District I), the Hangman Grits (District II), the Morte Slates (District III), and Lower Carboniferous Shales of the Boscastle Section of District VI. The comparison between areas belonging to these different groups is, however, rendered less direct, owing to the difference in the type of cliff, whether Hog's-back or Flat-topped.

A good example of the usual effect of sea erosion on a reef composed of highly inclined beds of unequal hardness, at Titchberry Water Mouth (District V), is seen on Plate LV, Fig. 2. The photograph is taken from the cliff above, looking down on the reef. We see how the sea has cut out each bed of shale level with the beach, while the harder sandstones still project, though even these are being slowly worn away. Similar

cases are shown on the left of the photograph of the sharp fold on Plate XLIV, Fig. 2, and in the reefs on the shore seen in the Frontispiece.

Some excellent illustrations of how the sea cuts out the softer beds may be seen close to Clovelly. The beds are here slightly inclined. In Plate LII, a thin bed of shale is shown, which forms part of the limb of an anticline. The sea has begun to work out the shales, while the harder rocks, above and below, are being worn away at a slower rate. The soft rocks are cut into by the pebbles, which are seen still in position as left by the tide, ready for further work when the waves again reach the cliff and furnish the motive power.

In the photograph on Plate LIII, a cavern, several feet in depth, is seen cut in a thick bed of shales, containing *Goniatite* nodules. This, again, has been excavated by pebbles rolled by the waves, the "cutters" being seen on the left as abandoned by the tide. This is an excellent illustration of an undercut cliff.

While it is the general rule that the softer beds are the first to disappear, there are many apparent exceptions to be noticed along the Devonshire coast, cases where beds of shale stand out prominently as reefs, or project from the cliff as high buttresses. In such instances, the harder sandstones appear to have been worn down before the softer rocks. Between Speke's Mill and Welcombe

Plate LIII

A thick bed of shales, containing calcareous nodules, cut out by the sea. The cutting boulders are seen on the left-hand side. West of Clovelly.

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Mouths, for instance, there are several great buttress reefs, projecting far towards low-water mark, which each consist of a single thick bed of almost vertical shales. These reefs are convex on the south side, and markedly concave and scoured out on the north by wave action.

It is also not uncommon, among the reefs standing only a few feet above the beach-level, to find shale beds in relief projecting above the sandstones. These require further study before they can be fully understood. They may be partly explained by the absence or scarcity of joints, and partly by the position which the particular bed occupies in a series of folded strata. Where joints, or planes of separation at right angles to the bedding planes, are numerous, both sandstones and shales are easily worked out by the sea (see p. 202, and Plate LVI); where they are few, the reefs and the cliff-faces are more stable.

Many of the great buttress-reefs of this coast, such as those near Bude (Plate XLVII) or near Bull Point (Plate XIV) consist, however, of several beds of sandstone and shale, tilted at a high angle, and projecting from the cliffs like great dykes. Their origin is not fully understood as yet, but in some cases they appear to represent all that is left of a limb of an anticline running seawards, and the most stable layers of that limb.

THE EROSION OF FOLDED ROCKS.

In approaching the study of the marine erosion of folded rocks we must bear in mind the natural stability of the cliff, depending on the disposition of the beds, and the direction of the attack of the sea. This is illustrated by three diagrams in

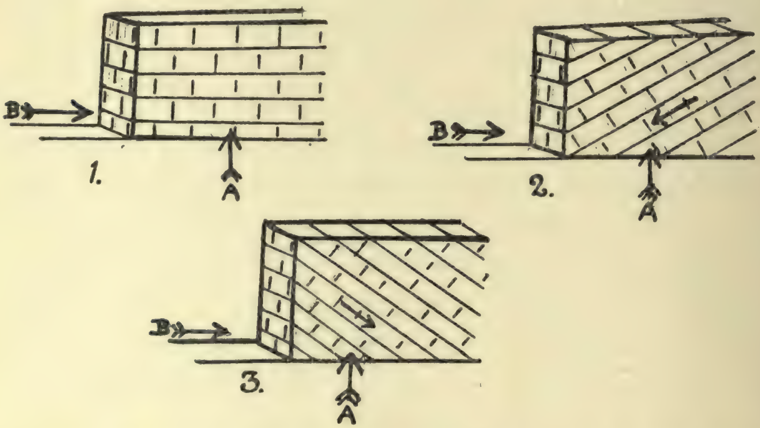

FIG. 9.—Diagrams to illustrate the stability of cliffs, which are being worked by the sea along the strike-face A, or along the dip-face B. In (1) the beds are horizontal, in (2) they dip seawards, and in (3) the dip is inland.

Fig. 9. In (1) the beds are horizontal and the cliff is stable, and also equally stable to the sea working, either at the strike-face A, or at right angles to the strike, B. In (2) and (3) the beds are inclined. In (2) where the sea attacks the strike-face, the cliff is fairly stable, where the dip-face B, the cliff is unstable. If the lower beds are removed, those above obviously tend to slip down.

In (3) the beds are dipping in the opposite direction. The strike-face A is fairly stable, as the beds tend to wedge into one another. The opposite face B, or, as we may call it, the counterdip face, is stable. Thus, the most unstable cliff is one dipping in the direction of the sea's attack. There are two fairly stable and three very stable cases.

In Devonshire and Cornwall, horizontal beds are rarely met with, and, as a rule, the tilted strata seen in the cliff are the limbs of folded rocks.

We now come to study the effect of sea erosion on folded rocks, beginning with simple folds, such as anticlines and synclines. We must, again, clearly distinguish between cases where the sea is working, either across the axis of the fold, or parallel to the axis. Naturally the most striking sections of the folds are seen where the erosion is taking place at right angles to the axis. In the photograph on Plate II, we see the effect of the sea working across the axis of a syncline. Such folds are rarely seen in the cliffs, because they are very unstable. If the heart of the fold (*i. e.* the central beds) is cut out by the sea, the higher portions of the same beds above tend to slip down and to be washed away. This has happened to some extent in the present case, where the central beds are only seen further inland, and the right-hand limb has been partly destroyed. There is another syncline, not figured here, lying a little

further North of the last example, which is near Bude, and offering an interesting comparison. Here we find a broad, shallow curve between the two limbs, owing to the removal of a large number of the central beds of the fold. As in the case of the anticlines, the sea attacks the central beds of the synclinal folds more effectually than those of the limbs, and they are the first to disappear.

The stability and permanence of anticlinal folds, which are being worked by the sea at right angles to the axis, is very remarkable, and is well illustrated by the photograph of Tut's Hole on Plate III, and the great anticline at Bude on Plate XLVIII. In the case of the former, the sea appears to have made very little impression as yet on the face, while in the latter a few beds of shale at the base have been removed. Further, both these folds stand well out from the cliffs, and denudation is going on more rapidly on their flanks, and on the cliff on either hand, than on the faces of the folds.

We will next study some cases where the marine erosion of the anticlines has reached a further stage. In the case of the inclined fold near Clovelly (shown on Plate XXVI), the beds of the heart of the anticline, not only the shales but also the sandstones, have been cut out. In the example of the low, rounded fold on Plate I, the lowest beds of sandstone, with the shale partings,

have disappeared for some distance into the cliff, while the stability of the fold remains unimpaired. The photograph on Plate XLIV, Fig. 2, shows a sharp fold, the heart of which has been cut out into a cavern. A still more striking case of a much eroded anticline near Bude is seen on Plate XLVI.

FIG. 10.—An eroded anticline, the crest alone remaining in the cliff, at Cleave Strand, in the Boscastle District.

Here again a large cavern has been worn in the heart of the fold by the complete removal of one or more of the thick beds of sandstone, as well as the associated shales.

Fig. 10 shows the crest of an anticline in the cliff at Cleave Strand, South of the Dizzard Point. The sea has here completely removed both limbs,

and undercut the cliff. The core or crest, however, remains just out of reach of the waves. Sometimes such crests occur loose on the shore as huge boulders.

Thus, we see that sea-eroded anticlines are wonderfully permanent and stable, as compared with synclines. The heart of the fold may be eaten out, it may lose a large part of both its limbs, but the crest at least remains, and the fold never, or but rarely, crumbles or loses its shape.

The fine anticlinal and synclinal folds near Mouthmill shown on Plate XXVIII, illustrate the difference in the stability of the two types. The anticline is here still intact, while the sea has cut out some of the lower beds of the syncline. In another case (seen on Plate XXXIV), near Hartland Quay, the syncline is retreating inland faster than the anticline, and we notice how the highest beds of the former at the top of the cliff tend to crumble, while those of the anticline stand out sharply.

On the other hand, contorted rocks do not as a rule differ much from inclined beds, as regards the sections produced by marine erosion. A comparison of Plates IV, XL and XLIX shows that such highly folded beds are worked back evenly by the sea, and often form a nearly plane surface in the cliff.

We now pass to consider cases where the sea is working *parallel* to the axis of folded rocks.

Plate LIV

Sea erosion of the coast, North of Hartland Quay. Smoothlands in the far distance.

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Here again synclines are naturally extremely unstable. When the sea, working along the axis of a series of folded rocks, has completely removed one limb of an anticline, the fate of the next limb, which is also that of the following syncline, is very swift, owing to the fact that the beds slope inwards and thus naturally tend to fall. A very clear case showing this condition of affairs is seen in Plate XXXII. The cliff section showing the waterfall is the landward limb of the syncline, which is stable. The heart of the fold is seen on the right-hand side of the photograph, and it is obvious that the seaward limb, a part of which is also shown, will be very easily demolished by marine erosion.

The sea erosion of the flanks of anticlines may be studied to great advantage in District V, where an almost endless series of stages may be observed.

The photograph on Plate LIV, looking North from Hartland Quay, gives a good idea of the type of cliff scenery evolved in such cases. The sea working along the strike of highly inclined sandstones and shales, dipping in the direction of the eroding force, tears out slab after slab from the cliff. The slabs separate along the joints, and when the lower portion has been cut into by the sea, they slip or tumble down, the inner layers being worked out before the outer, though, as is clearly seen in the photograph, several different beds are quarried, so to speak, at the same time.

The working out by the sea of slabs of sandstone is also very well shown in the photograph on Plate XX, where the Baggy Beds, at the Point of the same name, are seen. This cliff is nearly 200 feet high. On the left some reefs are seen nearly covered by the sea. These are all that remain of former beds cut out by the sea, like those which are shown a little further to the right, partially removed. The joints, along which the beds tend to separate into slabs, are also clearly seen in this cliff.

Plate XVI shows a similar case at Morte Point, where the cliff is perhaps eighty feet in height. The face of the section is more uneven, for the rocks here are the Morte Slates, which are worked out by the sea along the planes of cleavage, which vary in direction somewhat, or may even be quite irregular. Cf. Plates LVIII and LV, Fig. 1.

The lower portion of the cliff of Baggy Point, as seen on Plate XXI, also illustrates the way the sea works out the beds in slabs, by enlarging the bedding planes and joints, and thus loosening the solidity of the whole. The artificial method of quarrying such rocks, with the aid of a crowbar to enlarge the joints and bedding planes, follows the same principles as those in operation in nature.

We have yet a further case to consider. In the examples instanced above, the sea is working along the strike, or parallel to the axis of the folds. But, when the rocks are tilted almost vertical, they are

often eroded in a direction at right angles to the strike, across the bedding. Cliff sections of this nature may be frequently observed, as in the case of the sandstones and shales at Litter Mouth seen on Plate XLII, or the highly inclined shales near Westward Ho! (Plate XXIII). Such cliffs are remarkable as a rule for the vertical, clear-cut character of the sections which result, especially at the base of the cliff. The master joints, which are often very regular, appear to control the extent of the veneer of the cliff-face which is removed from time to time by the sea, aided by atmospheric weathering.

Such are the chief effects of marine erosion on cliffs composed of folded rocks. The great variety met with in the cliff sections is, as we have seen, due to the structure of the land which is being attacked by the sea, and the direction of its attack on the irregularities of the cliff-line. This constitutes one of the special features of interest presented by this coast, and it is hoped that the enumeration of the main types of sections illustrated here will help to explain the story of these cliffs.

SHORE EROSION.

Where the land shelves gradually seawards from the foot of the cliffs, as is commonly the case in North Devon, we find a gentle plane of marine denudation, which we may term the *wave plat-*

form, between the cliffs and the seaward limit of wave action. The higher portion of this platform is commonly described as the beach, or strand; and we have now to consider how the sea sets to work to erode this area. It need hardly be pointed out that the erosion here is almost entirely marine, atmospheric denudation taking little or no part.

It is not difficult to recognize different stages in the evolution of a wave platform. There is a juvenile as well as a senile period, with a mature stage between the two. The most striking characteristic of a juvenile wave platform is the amount of immovable material, in addition to debris which is easily shifted by the waves. The mature stage is shown on Plate XXVI, the material being here all, or nearly all, movable boulders, not yet ground down to pebbles. A semi-senile shore with its pebbles is seen on Plate LVII, and the final, senile stage on Plate XVIII, where sand is the predominating characteristic.

The agents at work on a wave platform are the waves and ground-swells (see p. 181) aided by the tides, currents, and on-shore winds. The effects are not, however, produced simply by the weight of the blows of the waves, but by the friction of the debris, large and small, which is moved forwards and backwards over the platform by each wave. Thus the erosion of a shore is continuous, even in the calmest weather, and at all states of the tide,

while cliff erosion is discontinuous, the chief damage occurring in times of storm and high tide. On the shore, however, the advancing or retreating waters of every tide roll to and fro boulders, pebbles, and sand over the surface of the wave platform, constantly eroding it and reducing it in height. The deeper the water, the larger and heavier are the tools used by the sea, for the carrying power or transporting power of a wave depends on its velocity, which is retarded in shallow water. It is a matter of common observation, for instance, that, in times of storm, the rougher seas are off the points, where the water is deepest, and the smoother in the bays, which are comparatively shallow. Thus the greatest amount of erosion is off the points, where not only the waves are largest, but their transported load of debris is heavier, and more powerful as an erosive factor.

JUVENILE WAVE PLATFORMS.

Examples of juvenile wave platforms may be found at almost any of the numerous points along the Devonshire coast. The shore here consists of jagged reefs, as yet not worn down to the level of the beach, with a considerable amount of debris of very large size, derived from the erosion of the cliffs. The most important feature of such a wave platform is the fact that the greater part of the

material is immovable. That is to say, where it does not consist of reefs still *in situ*, the masses of rock are too large and heavy to be shifted by the waves, even when at their maximum power in times of storm. A certain amount of movable debris is also associated, the position of which changes with every tide. Speaking generally, the movable debris has a much shorter life than the immovable, for it is ground to pebbles or sand within a comparatively short period, as the result of its attack on the immovable material, urged on by the sea.

The huge slabs, or beds, which fall from the cliffs on to the wave platform are in comparison wonderfully permanent, and remain little altered for many years. This is probably due to the fact that they are quarried from the cliff by the sea by an enlargement of the principal bedding planes and master joints, and, as they lie on the shore, only minor planes of weakness present themselves to the action of the waves. Under the forces of marine erosion, and chiefly by means of the movable shore debris urged on by the waves, the first change which takes place is a rounding off of the angles and a planing down of the sides of these huge boulders, which thus become smoothed and polished. In course of time, however, they become more and more worn, and tend to break up by the enlargement of the minor planes of weakness, and they thus pass from the immovable to the movable state.

FIG. 1.—Marine erosion of Morte Slates at Bennett's Mouth (Mortehoe District).

FIG. 2.—Marine erosion of highly inclined beds of sandstone and shale at Smoothlands, as seen from the cliff above (Hartland District).

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MATURE WAVE PLATFORMS.

The next stage, the mature wave platform, is characterized by the abundance of rocky debris, which is constantly moved by the waves, but which has not yet reached the pebble condition. The shore at the foot of the anticline seen on Plate XXVI, and also on Plate XXVIII, is in the mature condition. The derivation of the small boulders seen here, from the immovable masses of rock, characteristic of a juvenile wave platform, has been explained above.

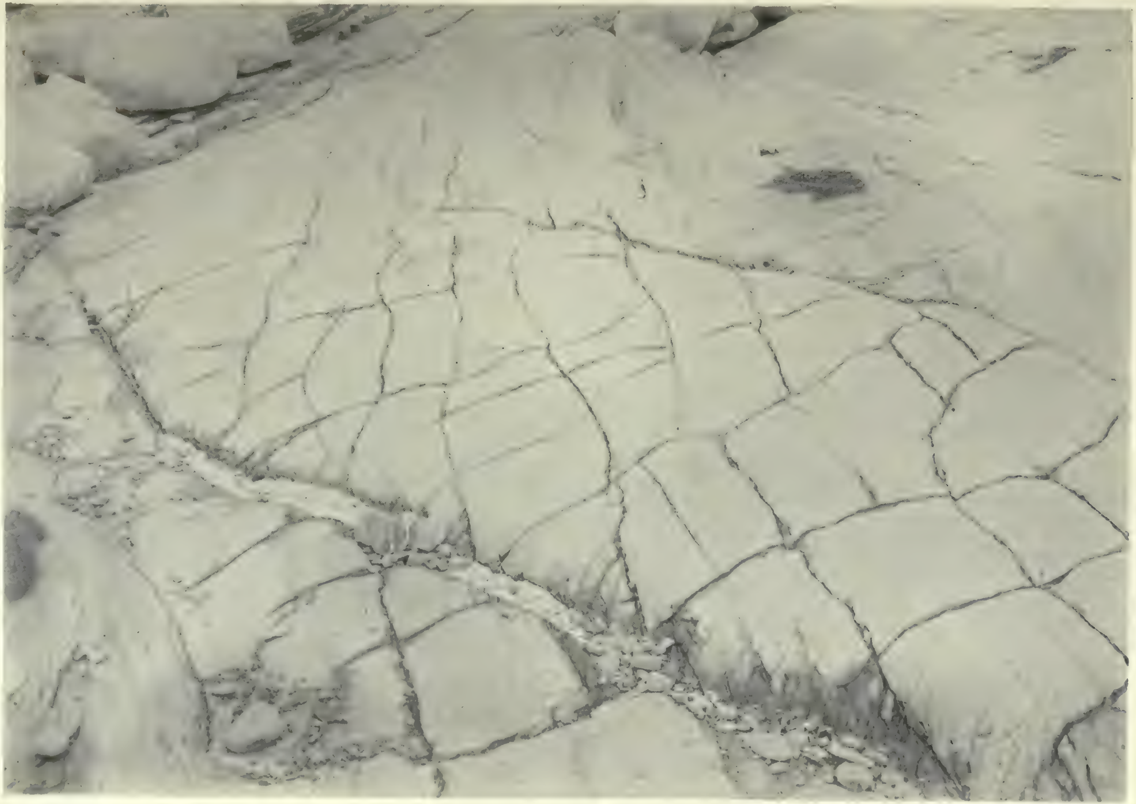
The occurrence of reefs projecting above the general level of the beach is also equally characteristic of the mature wave platform. Where these reefs are interbedded sandstone and shales, the softer shale beds are sometimes cut out almost to the base of the reef, as is seen on Plate LV, Fig. 2. In other cases the interbedded shales are only a little more deeply worn than the sandstones (Plate XLIV, Fig. 2), while sometimes the shales persist longer than the sandstones (see p. 142). In the two former cases, the isolation of the sandstone beds, by the removal of the shales, is the first stage in their erosion. Once the beds are isolated, the sea sets to work to enlarge the joints, and, eventually, block after block is removed from the higher portion of the reef.

We turn next to cases where the reefs consist

of sandstones alone. There are, however, few good instances to be met with of this type of reef in North Devon. The wave platform of the coast from Porlock to the Foreland in District I, consisting of the Foreland Grits (Plate V), has reached the semi-senile stage, with a well-marked pebble ridge at the foot of the cliffs, while the rest of the higher part of the platform consists of sand and other fine material, with a few unhewn boulders scattered here and there. Reefs are rarely exposed except at low water of spring tides.

The coast occupied by the Hangman Grits, between Heddon's Mouth and Combe Martin (District II), has a steep wave platform, and the sea recedes very little from the cliffs even at low tide, so this ground is not favourable for the study of the reefs. What happens, however, where a bed of sandstone between high and low water marks is being worked out by the sea, is clearly seen on Plate LVI, a case occurring in the Clovelly District. We notice that the master joint is here filled by a resistant quartz vein, seen on the left of the photograph. The minor joints, however, are slightly enlarged, and appear as a network of small cracks, the edges of each block being smoothed down, and the cracks thus becoming funnel-shaped above. When one block gives way, others are quarried out in a regular succession, and this is seen in progress at the right-hand side of the photograph.

Plate LVI



The marine denudation of a bed of sandstone, between high and low water marks in Bideford Bay. The enlargement of the joints, and a quartz vein are clearly seen.

[*To face p.* 202

There remains a third type of reef, that composed of slates, which may be well studied in the Morthoe District, where the slates of the same name form interesting reefs, which have been described as the "cruel Morte Slates." The form of the reef is here determined by the cleavage planes, which are often irregular, as well as by the irregular fracture, and the folding of the beds. Where the beds are highly tilted, the sea enlarges the cleavage planes, and breaks off the higher portions of the slabs with an irregular cross-fracture. Hence the summit of the reef consists of jagged, toothlike, irregular projections, as is seen in Plate LV, Fig. 1, and especially Plate LVIII. A photograph of the erosion of the Ilfracombe Slates on Plate XIII also shows the working out of the slates of the cliff, by the enlargement of the cleavage planes, and their irregular fracture, especially at the left-hand side.

SEMI-SENILE WAVE PLATFORMS.

Examples of semi-senile wave platforms are abundant along the Devonshire coast, especially in the Clovelly District. They may be recognized by the existence of high pebble ridges at the foot of the cliffs, and by the much denuded reefs (Plate LVII). Such a beach shows how the sea sorts out the materials according to size, the largest debris being thrown down at high, the smallest at low water mark. This is due to the rapid forward, as

compared with the slower backward progression of the wave, the transporting power varying with the velocity. Thus the larger fragments, when once they are moved forward, are not withdrawn by the weaker backwash.

The pebbles forming the ridges, or "popples" as they are sometimes termed in Devonshire, are the finished products of the erosion of sandstone boulders. All the angles have been rounded off by the jostling of one pebble against another, and the surfaces are planed down evenly and polished. How severe this smoothing process has been, is shown by the quartz veins, which often traverse the pebbles, as they did the original sandstones (Plate XXII, Fig. 1). These veins are harder and less easily polished than the sandstones, yet they very rarely stand out in relief, but as a rule are planed down level with the surface of the pebble which they traverse. This photograph also demonstrates the great variation in the size and shape of the pebbles forming a ridge. They lie pointing in all sorts of directions, which is due to the fact that they are chiefly rolled, and not lifted by the sea, when near their place of deposition. Their movements are thus to a considerable extent controlled by the neighbouring pebbles, and they come to rest, so to speak, as best they can. They are deposited at, or above high-water mark, and the flat-topped nature of the ridge, which is such

Plate LVII

The pebble ridge and denuded reefs at Abbotsham Cliff, near Bideford, looking West across Bideford Bay.

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a prominent feature, is probably due to the variation in the height of the tide day by day.

One of the most interesting facts in connection with these pebble ridges is that they shift their position. A whole ridge has been known to move as much as thirty feet as the result of a single exceptional gale, and, even after a strong winter's gale, great alterations in the pebble ridges are usually noticeable. Further, the individual pebbles travel along the coast. From Boscastle to Hartland and Bull Points, the direction of the migration of the pebbles is from South to North, while between Bull Point and Porlock it is from West to East. This is due to the fact that the prevailing winds are from the South-west, and more especially because the tides and currents set up the coast from the South.

The pebbles as a rule travel slowly along the Devonshire coast, though elsewhere the rate is said to be sometimes as much as half-a-mile a day. The shingle is driven forward by the blow of one pebble upon another, as they are rolled up the beach by the advancing tide. The waves break in upon the beach obliquely to the trend of the shore-line, owing to the direction of the prevailing winds, and thus move the pebbles obliquely along it. But although the wave pushes the pebbles up the shore obliquely, the backwash, which is at right angles to the trend of the beach, tends to carry them

back towards the sea. Thus the pebbles pursue a zigzag course, the cycle of which is like the letter Z, where the horizontal strokes represent the direct backward effect of the backwash, and the connecting link, the forward oblique movement of the wave, the sea being on the left, and the land on the right of the Z, or *vice versa.*

The pebbles travelling along the coast often meet with obstacles to their progress, such as projecting points, or the mouth of a large river, as in the case of the pebble ridge of Westward Ho! (p. 90). In such cases they tend to accumulate, and to form large ridges, which may continue in being for a considerable period, until a particularly violent storm arises in conjunction with a high tide, when the waves scour them out of their retreats.

SENILE WAVE PLATFORMS.

Where the supply of new materials, eroded from the cliffs, has ceased, or where the onward march of the pebbles along the coast has been arrested, the sea sooner or later grinds down the movable debris of a wave platform to a finer and finer state, and ultimately not only the higher part of the beach, but the much denuded reefs nearer low-water mark, become choked with a great accumulation of sand (Plate XVIII). Thus a sandy beach is a sure sign of a senile wave platform. It may contain occasional reefs, as, for instance, to the

Plate LVIII

A reef of Morte Slates between Woolacombe and Mortehoe.

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North of Bude, where the wave platform is only entering on the senile condition, but in course of time even these often tend to become buried by the accumulating sand. The sand, unlike the pebbles, is comparatively stationary, and does not as a rule travel up the coast unless aided by the wind. Wind-blown sand tends to migrate from the beach on to the land, and will accumulate as dunes at the foot of the cliffs (Plate XVIII), where its advance is barred in that direction. On the other hand, where the land slopes gently seaward the dunes will travel inland a considerable distance, and often ruin large areas of what would otherwise be fertile land. Braunton Burrows (p. 83) is the best example of a senile wave platform on this coast, and others occur at Woolacombe, Croyde, and Widemouth, and have been already discussed in detail in Part I.

Such is a brief sketch of the salient features of coast, cliff, and shore erosion as exhibited in North Devon and Cornwall. The conditions are often very complicated, and there is need for much further study before one can fully understand all that is exhibited by this stretch of coast. At the same time, it is hoped that this short summary will enable the visitor to find some explanation of the more interesting features presented by these shores.

CHAPTER VIII

THE COASTAL WATERFALLS; THE STAGES IN THEIR EVOLUTION

In the preceding chapters, we have called attention to the fine series of coastal waterfalls in North Devon and Cornwall, which form one of the most interesting of the geological features of this coast-line. Such coast falls are very rare in Europe, except in Scandinavia. A few examples are found elsewhere in the British Isles, but there is undoubtedly no stretch of coast-line in these islands which offers such a grand and varied series of waterfalls as is to be found in North Devon and Cornwall. It is especially interesting to find that one can here trace all the main stages in the evolution of a coastal waterfall.

The present chapter will be devoted to a comparative study of the waterfalls which have been already described in detail in the First Part of this book. As some of them, which show typical stages in the evolution of a coastal waterfall, are situated not far distant from one another, it is possible for

those who visit these coasts, and, in particular, the Hartland District, to compare them by personal inspection, and such a comparison will be found to possess great geological interest.

The existence of all these coastal falls is primarily due to the formation of what are known as "*hanging valleys*," by marine erosion. By the term "hanging valley" is implied a valley, with or without a stream, which at some portion of its course comes to an abrupt end in the shape of a more or less sheer precipice. Such hanging valleys are very common in mountainous countries, such as Switzerland, and are due to complex causes, the exact nature of which may vary in different cases. Where such a valley is watered by a stream or is filled with a glacier, we find at its termination either a waterfall, or an ice fall or hanging glacier. A very large number of inland waterfalls are primarily due to the existence of hanging valleys, perched high up above the main valley of the district.

In the case of the hanging valleys of the Devon and Cornish coasts, their seaward terminations have been cut away more or less sheer by the action of the sea, the existence of cliffs at the mouths of many of the streams being, of course, the work of the sea. Here, just as in the case of inland hanging valleys, we frequently find a waterfall, the exact physiognomy of which depends

on several factors, the discussion of which we will defer until the next chapter.

If, however, we study the seaward terminations of the streams of this coast-line we shall find that, in other cases, there is no hanging valley and no waterfall. The streams here simply meander down a gentle inclination on to the beach. This is the case with all the rivers and the larger streams in Devon and Cornwall. What, then, is the relation between this type of river mouth and the case where the stream ends in a sheer waterfall over a high cliff on to the beach? This is the subject of discussion in the present chapter.

The fact is that, at the mouths of all these streams, large or small, there are two forces at work. Marine erosion tends to form a cliff and thus to initiate a coastal fall. But the action of the stream itself is to lower and to cut back its bed, and this tendency is often assisted in Devon and Cornwall by the general weathering or decay of the walls of the valley, in the way which we shall shortly explain. The actual result achieved depends on which of these two forces, marine or fluviatile, happens to be the more powerful in any particular instance, and one of the most interesting geological studies presented by this coast-line is due to the fact that it exhibits so many instances in which these two forces are nearly equal, or where one has only got the upper hand to a limited extent.

At the outset we must distinguish clearly between those factors which determine the *existence* of coastal waterfalls, such as those above mentioned, and the factors which call forth the *special features* or physiognomy of such falls. We will reserve a consideration of the latter until the next chapter.

If we imagine an elevated inland watershed, drained by numerous rivers and streams flowing in various directions, and if we suppose that on one side this watershed has been suddenly cut into by the sea, so that only the head waters of the drainage remain, we should find that, on the seaward side, the streams would form splendid, sheer, coastal falls. This is practically the condition of affairs which we meet with in Devon and Cornwall, but here, however, the attack of the sea on the watershed has not been sudden, but slow and very gradual. Consequently, while the larger streams and rivers have been able to work faster at lowering the inclination of their valleys at their mouths than the marine erosion has been able to cut back the cliff, yet the smaller streams, possessing less power of eroding their beds, have worked at a relatively slower rate than the sea, and consequently end in hanging waters or coastal falls.

THE PRIMITIVE SHEER FALL TYPE.

The most primitive type of coastal fall is that which we will call the *sheer fall*, of which Litter

Water in the Hartland District (p. 137, Plate XLII, No. 55 on Map No. 1) is the best example on the whole coast. This stream, which is of fair size, ends in a sheer leap of seventy feet over the cliff on to Litter Beach. Its valley is the simplest and most perfect type of hanging valley to be met with in Devon or Cornwall. The existence of this type of fall depends primarily on the fact that the sea is here cutting back the cliff much faster than the stream is eroding its bed. In the photograph of this fall on Plate XLII, it will be seen that the stream has cut down some distance into the cliff at the top of the fall, but yet the sea is attacking the cliff more rapidly than the stream can cut through it.

This fact alone is not, however, sufficient to account for all the features of this waterfall. The sheer nature of the leap depends on several factors, which are those which determine the physiognomy of all waterfalls. In this case one of the most important is that the rocks are tilted at a very high angle, so that the beds stand almost upright. Another is that the stream is flowing in the direction of the *strike* of the rocks. It is obvious that, if this cliff were landslipped, instead of being cut nearly vertical by the sea, the nature of the fall would be very different. Further, as we shall see in other cases, where a stream flows in the direction of the *dip* (*dip streams*) or a direction

contrary to the dip (*counterdip streams*), this fact has a profound influence on the physiognomy of the fall. In such instances the fall, instead of being sheer, is nearly always broken into leaps or cascades.

There is only one other sheer waterfall on this coast, and that is a very small stream at Greenacliff (p. 98), near Westward Ho! in the Clovelly District, which is only about fifteen feet high.

As a simple case of an almost sheer fall, slightly modified owing to the fact that the stream is flowing in the direction of the dip, that at Blegberry Mouth (p. 119, Plate XXXII, No. 49 on Map No. 1) may be instanced. This stream forms a fall over a cliff about twenty-five feet high, down one limb of a syncline which is being rapidly denuded by the sea. The fall is not sheer because the beds dip towards the shore and the sea, as is plainly seen at the right-hand corner of the photograph on Plate XXXII. The shales, over which the water passes, are unequally eroded, and some beds are harder and more resistant than others, hence the fall is broken into several small leaps. The same features are, in greater or less degree, common to the majority of the coast falls of Devon and Cornwall.

THE INITIATION OF A CANYON.

Next let us take the case where the sea is only denuding the cliffs comparatively slowly, the fall

being protected by the presence of a pebble ridge or some other circumstance. If the stream is of fair size and velocity, it will begin to cut its channel backwards and downwards, and the first portion of the valley to be deepened is at the top of the fall. This is also the first part of the stream which will eventually reach base-level (when erosion ceases), which, in this case, is equivalent to sea-level. As the top of the fall retreats inland, we find a deep *canyon* cut in the cliffs between it and the sea. A canyon is typically a U-shaped cleft, though owing to the decay of its walls by weathering, and to the tendency of the soil of all steep-sided valleys to travel downwards (*soil-slip* as it is called), it will, when old, become V-shaped.

The floor of the canyon is gradually reduced to base-level as the waterfall retreats inland, but in the early stages of what we may call the immature canyon, it may be worn away unevenly, the irregularities giving rise to a series of falls. A very beautiful example of such an immature canyon is presented by the lower part of the fall of Milford Water at Speke's Mill Mouth (p. 131, Plate XXXIX, No. 52 on Map No. 1) as seen from the shore. The fall, which is seen at the head of the canyon, marks the point to which this waterfall has retreated from its original position above what is now a pool on the beach, seen in the immediate fore-

Plate LIX

The canyon of Milford Water, at Speke's Mill Mouth, looking seaward, from above the second fall.

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ground of the photograph. It has not, however, persisted as a sheer fall, but has worn its channel back unevenly, with the result that there are now three falls, of which only two are seen in this photograph. The top of the fall, in the background, is at present at least 100 feet above sea-level. This fall was once very much higher, probably at least 200 feet. In the future, provided the sea does not get in and destroy the canyon, the stream will cut down the remaining 100 feet, and the floor of the canyon will then be at sea-level. Plate LIX shows the same canyon looking seawards from its head.

This particular instance at Speke's Mill Mouth is quite unique on this coast as an example of an immature canyon. There are other cases, as for instance at Greenacliff (p. 98), Mortehoe (p. 75), and Pentargon (p. 160), where we find a canyon-like cleft with a waterfall at the head, but in all of these it is the sea, and not the stream, which cut the canyon.

THE MATURE CANYON.

On the other hand, good instances of *mature canyons*, with fair-sized falls at their heads, are not lacking in Devon and Cornwall. One of the best of these is seen at the Mouth of the Abbey River (p. 121, Plate XLIV, Fig. 1, No. 50 on Map No. 1) in the Hartland District. At the

seaward end of this stream we find a long canyon, not quite straight, which is sixty-four yards in length and about fifteen feet in height. It has been formed by the stream's erosion along the strike of the sandstones of an anticline. At the head of the canyon we have the waterfall figured on Plate XXXIII, and which has been already described (p. 122).

A less perfect canyon may be also studied, a short distance to the North at the Mouth of Titchberry Water (p. 116, Plate XXXI, No. 48 on Map No. 1). This is about sixty yards in length, but it has been largely obliterated by landslips on both sides. A fall is, however, present at its head, which is of a very different type to that of the Abbey River, for reasons which we shall discuss in the next chapter.

THE DEGRADATION OF THE FALL.

As the stream cuts its way back into its bed, and the waterfall retreats, the canyon becomes longer and longer, and the fall shorter and shorter. Usually the canyon is more or less obliterated by landslips or by soil-slip. Encroachments by the sea also tend to destroy canyons. In the end we may have to penetrate inland some little distance to discover the last lingering stages of the fall, now reduced to small rapids, and we may also have considerable difficulty in locating the last remnants of the canyon.

The seaward termination of Marsland Water (p. 136, Plate XLIII, No. 54 on Map No. 1) at the boundary of Devon and Cornwall, offers an excellent illustration of a senile canyon, and a degraded inland fall. As is seen in the photograph, which is taken looking seawards, from a position on the hill-side of the valley which is roughly on the line of the last remnants of the fall, the winding canyon is still well marked in places, though much of it has disappeared as the result of soil-slip. The fall, now at least a quarter of a mile from the beach, is reduced to two cascades, each only three or four feet in height.

The valley of the East Lyn (p. 41, No. 15 on Map No. 1), from its mouth to "Waters Meet," is probably another example of a canyon, with a senile, inland waterfall near its junction with Hoaroak Water.

BASE-LEVEL.

The final stage, so far as the mouths and lower portions of the streams are concerned, is *base-level*. This has been reached by all the larger, and many of the smaller, streams in West Devon and Cornwall. Of a total number of about seventy-seven streams, thirty-three are at base-level at their mouths, while nearly the same number end in coastal waterfalls of one type or another. The remaining ten include those streams and brooks

whose mouths have been so altered by man that it is now very difficult, if not impossible, to ascertain what was the original condition of their seaward termination.

Bennett's Mouth (p. 72, Plate LX, No. 34 on Map No. 1) in the Mortehoe District presents an excellent example of a small stream, which has reached base-level at its mouth. Its valley has very steep sides, from which an excellent view of the lower termination of the stream may be obtained (Plate LX). The slope of the valley floor, at its seaward extremity, is now so gentle that at high tides the sea works its way into the mouth. Sea-cut reefs are seen in the photograph on Plate LX, at the right-hand bottom corner.

While all the smaller streams of this portion of the Devonshire and Cornish coasts, which are now at base-level, no doubt ended at one time in coastal waterfalls, it is not known whether this is also true of all the larger rivers such as the Torridge and Taw. The original seaward terminations of these rivers have long ago disappeared beneath the sea, and we do not know what was the original configuration of the land, now submerged beneath the waters of the Bristol Channel and the Atlantic. If these streams ended on a slope, gently inclined towards the sea, naturally no coastal fall would be initiated, for it is only where a watershed is being rapidly cut into by sea erosion that such coastal falls are likely to occur.

Plate LX

The termination of Bennett's Water, an example of a stream at base-level at its mouth (Mortehoe District).

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CHAPTER IX

THE COASTAL WATERFALLS; THE FACTORS WHICH DETERMINE THEIR EXISTENCE AND PHYSIOGNOMY

In the preceding chapter we have traced the different stages in the evolution of coastal waterfalls. We have now to consider the factors which determine their existence, and which initiate the special features of their physiognomy. It will be remembered that these falls are often extremely unlike one another, and we now have to inquire into the causes of this dissimilarity.

Of the factors which control the existence of a waterfall, we are inclined to place first the nature of the sea escarpment. Attention has been repeatedly called to the two distinct types of cliff to be met with along this coast (p. 14, Figs. 3 and 4), the Hog's-back and Flat-topped cliffs. The waterfalls over these escarpments are, for the most part, distinct in type. In the area in North Devon occupied by Devonian rocks, where Hog's-back cliffs prevail exclusively, the waterfalls are small and comparatively uninteresting. This is due to

the fact that only the lower portion of the long seaward slope is as a rule worked by the sea, and thus the height of the fall is trifling in most cases. The falls at Glenthorne (p. 37, Plate VII, Fig. 2) and Woody Bay (p. 47, Plate VII, Fig. 1) are typical examples. Hollow Brook Fall (p. 51) and Pentargon (p. 161), the latter on the Lower Carboniferous area of the Boscastle Section of North Cornwall, are the two most striking cases of the sheer falls over Hog's-back cliffs, corresponding to Litter Water (p. 137), a sheer fall over the Flat-topped type of cliff. In each instance, however, the sea-cut section only involves part of the long seaward slope, whereas that of Litter Water extends to the top of the cliff. Further, in the case of a Hog's-back cliff, the slope over which the streams flow is so steep, and consequently their erosive power is so great, that they tend to cut deep into it above the lower part of the cliff, which is undercut by the sea, often forming inland cascades during their course down the long seaward incline. Thus the waterfall retreats inland in a quite different way to that observed on a coast where the Flat-topped type of cliff prevails. We here meet with no river-cut canyons, as opposed to sea-eroded gullies, nor are such likely to occur.

On the other hand, the Flat-topped type of cliff lends itself naturally to the production of striking coastal falls, especially when eroded sheer by the

sea, unless extensive landslips have taken place. The part played by the escarpment in producing such a fall as that of Litter Water, Plate XLII, is too obvious to need discussion. In general, the higher the cliff, if of the Flat-topped type, and the sheerer its sea-cut face may be, the finer the waterfall.

The influence of the nature of the escarpment in determining the existence of a waterfall is brought home to us when we study the cases to be found along the Devonshire and Cornish coasts where waterfalls have been obliterated by landslips. As has been already pointed out, the Flat-topped type of cliff seems to be more liable to landslips than the Hog's-back slopes. Good examples of waterfalls obliterated by landslips occur at East Hobby Water (p. 104) in the Clovelly District, and at Sharnhole Point Fall (p. 154) and Cleave Waterfall in the Dizzard Region of the Boscastle District. These are all small streams, and now they simply trickle down the broken surface of the landslip, their course being determined entirely by the irregularities of the cliff. As waterfalls they have practically ceased to exist, at any rate until the sea manages to remove the landslipped material.

SEA EROSION AND STREAM EROSION.

Another factor which determines, not only the existence, but the physiognomy of a coastal fall,

is the balance of power between stream and sea erosion. Instances occur where both these forces are almost negligible, as in the case, just discussed, of the small stream trickling down over the broken surface of a landslipped cliff. Usually, however, either fluviatile or marine erosion gets the upper hand. Where the sea is actively eroding the cliffs, and cutting them back more rapidly than the stream can eat into its bed, the sheer type of fall, as at Litter Mouth, Hollow Brook, and Greenacliff Water, or a semi-sheer fall such as that at Blegberry Mouth (p. 119, Plate XXXII) may result. On the other hand, where the mouth of the stream is protected in some way from the inroads of the sea, then the stream gets the upper hand, and a canyon is initiated, as has been demonstrated in the case of Milford Water Fall (p. 125), and the Abbey River (p. 121).

The factors which especially influence the physiognomy of coastal falls are the direction of the stream above the fall, in relation to the strike or dip of the rocks, the relative hardness or softness of the beds exposed in the cliff section, the presence of joints, and the degree of slope of the sea-cut section. In cases where only one or two of these factors are of importance, simple modifications of the sheer fall type result, as we shall see. If several, of nearly equal importance, are in operation, the modifications are more considerable, and the fall

becomes compound, and consists of a chain of closely linked falls.

THE RELATIVE HARDNESS OR SOFTNESS OF THE ROCKS.

The relative hardness or softness of the strata passed over by the stream, whether above or at the fall, has a profound influence on its course, when beds of two different degrees of hardness alternate. A stream tends to cling to the softer rocks, and, when it leaves them to pass over harder rocks, it will endeavour to return to the more easily eroded beds at the first opportunity. A stream flowing along the strike of a soft bed will cross a hard bed in the direction of its dip, and then tend to regain the strike direction of another, or even the same, soft bed. This change of direction, from the strike to the dip, and then back to the strike, may be clearly seen in the Ω curves of Titchberry and Blegberry Waters (pp. 116 and 119) above the falls.

Where the sea-cut cliff section is perfectly vertical, the relative hardness or softness of the beds is naturally not a factor influencing the physiognomy of the fall. In the case of Litter Mouth (Plate XLII), the water passes over the face of a single vertical bed as a sheer fall, and the same is also true of the highest fall of Milford Water (Plate XXXVII), though here, of course,

the section has been cut by the stream itself. But it is more commonly the case that the section is inclined, and not vertical, partly owing to the fact that the sea-eroded rocks are folded. In these circumstances, if the section consists of alternating beds of unequal hardness, as at Freshwater Fall, near Clovelly (Plate XXV), or Blegberry Fall (Plate XXXII), the softer beds are worn away before the harder. The cascade modification of the sheer-fall type is thus initiated, the water leaping from the ledges formed by the isolation of the harder rocks. In the latter case, above mentioned, the sea has worked out the face of the cliff unevenly, parts of several different beds of the limb of the syncline, of unequal hardness, being exposed.

The fall of Beckland Water (p. 109) in the Clovelly District shows the cascade modification in a more advanced degree, and Peppercombe Water, in the same district (Plate XXIV), is an excellent example of a senile fall, broken into cascades, owing to the unequal hardness of the Triassic beds, over which the stream passes.

The cascade modifications may be traced in the great majority of the coastal falls of Devon and Cornwall in greater or lesser degree. As the coastal fall becomes degraded, and the stream cuts back in the cliff, modifications of this type often become more pronounced, as, for example, in the case of the Abbey River Fall (Plate XXXIII), or

Plate LXI

The Fall of Wargery Water, South of Hartland Quay, from the cliff, looking down on the beach.

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still more so in the senile stages seen at Marsland (p. 136) and elsewhere. From the point of view of scenery, the effect of this modification depends on the size of the stream. Where the stream is large, the fact that the fall is broken into leaps often adds to its beauty ; where it is small, it loses in picturesqueness by the splitting up of the water into small driblets.

STRIKE OR DIP.

As we have pointed out, a stream, just above the fall, may be flowing along either the strike or the dip of the beds, in accordance with the relative hardness of the rocks over which it passes. Titchberry Water (Plate XXXI) Blegberry Water (Plate XXXII) and Milford Water above the first fall (Plate XXXVI) are examples of strike streams with dip falls. Blegberry Water ends on a beach, but both the other streams return to the strike direction along softer rocks below the falls. On the other hand, where the section over which the stream falls is inclined, and the beds are of unequal hardness, we commonly find modifications due to a change in the direction of the water during its course down the cliff. The dip slope tends to capture the stream. A soft bed is worn out, and the water tends to flow along and down, instead of over, the ledge of hard rock thus isolated. Thus a peculiar type of fall, which we

may term a Gutter Fall, is initiated. Wargery Water shows the initial stage in the production of a gutter fall, though the photograph on Plate LXI does not emphasize this fact, since the stream is here seen in profile. The gutter is at the head of the lower leap seen in this photograph. A more pronounced gutter fall is produced by the Tidna at Higher Sharpnose Point, as has been described on p. 140, Fig. 8. A joint, however, in this case plays an important part, where the fall returns to the vertical direction. Such gutters may occur at the top of the fall as in the case of the Tidna, or at the bottom as in the case of Pentargon (p. 161), or at any point in the cliff section. The fall becomes compound, except where the gutter portion is at the base of the section.

The dip gutters mentioned above are sometimes extremely striking, but it must be remembered that strike gutters also occur, or, in other words, a strike slope may capture part of a fall as well as a dip slope.

Strike gutters, however, are only very gently inclined, and are thus less conspicuous. One of the best examples occurs below the first fall of Milford Water (p. 125, Plate XXXVIII, Figs. 1 and 2), while the lower portion of Titchberry Fall (p. 116, Plate XXXI) is also a strike gutter.

We have still one further case to consider, namely, what we may term a Counterdip Fall.

The Second Fall of Milford Water at Speke's Mill Mouth (Hartland District).

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Where the strata of the cliff section, over which the stream passes, are dipping inland, and the water is, in this part of its course, flowing in the opposite direction to the dip, cascade modifications are extremely likely to arise, where the rocks consist of alternations of hard and soft beds. This condition of affairs is clearly seen in the second fall of Milford Water (Plate LXII). Other examples are Hollow Brook (p. 52) and Sherrycombe (p. 55) Falls in District II, and the fall at Sandy Mouth (Plate XLV, Fig. 2) in District V.

JOINTS.

We have now to consider the effect of *Joints*, in conjunction with alternations of hard and soft beds, in determining the physiognomy of waterfalls. In examining the coastal waterfalls of Devon and Cornwall, it will be commonly noticed that they are often double, the stream dividing into two branches over the face of the cliff. This is due to the fact that the stream quickly cuts through any soft beds at the head of the fall, and that it is the joints of the harder and more resistant rocks which there determine initially the direction taken by the water over the cliff.

There were at one time, as has been pointed out on p. 120, two falls at Blegberry Mouth (Plate XXXII), their direction being influenced by the

joints in the sandstones cut through at the head of the fall (Plate XXX). West Hobby Water (Plate XXV) Wingate Water (p. 37) and Hollow Brook (p. 51), the two last named being waterfalls over the Hog's-back Cliffs of Districts I and II, are other examples of bifurcated waterfalls. In the case of Hilly Mouth, in the Mortehoe District, we also meet with a similar fall, the branches here being apparently determined by two cleavage planes in the Morte Slates of this cliff section.

In the case of the gutter falls just discussed, whether strike or dip gutters, it is often a joint which changes the direction of the fall, as, for instance, at the end of the strike gutter of Milford Water (p. 131) and of the dip gutter of the Tidna (p. 141, Fig. 8).

But by far the most interesting "study in joints," if we may so call it, so far as Devonshire waterfalls are concerned, is the fall of Strawberry Water at Welcombe Mouth (Plate XLI and Plate XLV, Fig. 1), described on p. 135. Here jointing is obviously the principal factor in determining the physiognomy of the fall, though the effect of alternating beds of hard and soft rocks is also clearly seen.

From such examples of the coastal falls of Devon and Cornwall as have been instanced here, it is obvious that the factors which determine the physiognomy of the falls are varied, and that they

are due ultimately to the geological structure of the land itself. At the same time the great variety met with along these coasts is explained by the fact that both the streams and the sea are eroding *folded* rocks. The results differ in each case according to the way in which the folds are being cut by the streams or by the sea, and according to the number and relative importance of the factors combining to impress their seal on the particular fall.

CHAPTER X

THE SEA-DISSECTED VALLEYS OF NORTH DEVON

It is a matter of common observation that the great majority of all the rivers and streams of this country enter the sea more or less at right angles to the coast-line, unless their mouths have been diverted by bars of drifted sand or shingle. It does not appear, however, that the significance of this fact is generally realized. The explanation can only be that coasts are carved out by sea erosion in conformity with the physiognomy of the land, or, in other words, that the nature of the land surface plays a considerable part, as we have already concluded (p. 171), in determining the features of the coast-line.

There are, however, rare exceptions to the rule. A river or stream, on approaching the shore-line, may bend and run parallel to it for some little distance before it actually enters the sea. A study of what happens in such exceptional cases only serves to emphasize the truth of the conclusion above mentioned. As a rule, the sea will cut through the cliff at the bend and dissect the lower portion

of the valley, and the waters of the stream will be captured by the sea at some little distance from the original mouth, so that the stream now enters the sea at right angles to the coast.

There are at least two, or possibly three, good cases of such dissected valleys in North Devon which are particularly interesting in this connection. They are also very rare phenomena. In no case have the streams yet reached base-level at their present mouths, and their valleys are being rapidly cut into at the present time by sea erosion.

WARGERY WATER.

The first instance of a sea-dissected valley which we will study is Wargery Water, which ends in a small waterfall, which we have already discussed (p. 124), on the northern side of St. Catherine's Tor, near Hartland Quay Hotel. This stream rises near Wargery Farm, and has a total length of about one and a half miles. For a quarter of a mile from its source it flows North, for the next half-mile West, and then for another half-mile it bends gradually to the North-west, through Wester Wood, and receives a tributary from the North-east. At its present termination it is still flowing in a north-westerly direction (Plate LXI).

If we examine the present mouth of this stream, we shall find that while the stream itself goes over the cliff, the nearly level bottom of the valley, and

also one of its walls, continue along the cliff to Hartland Quay. The contours of this landward wall are shown on the 6-inch map (see also Fig. 11). We shall also find that it is possible to trace

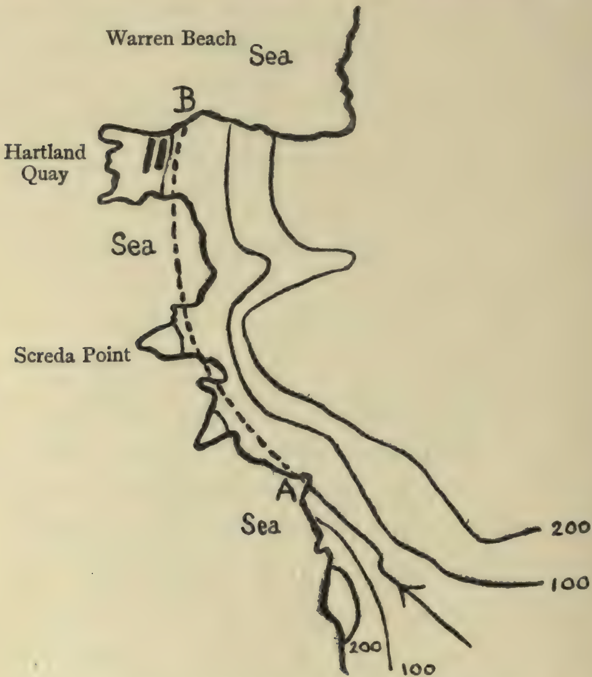

FIG. 11.—A map of the former course of Wargery Water. A, present waterfall; A–B, former course of the stream. The 100-feet contours are shown as continuous lines. (Scale, 6 inches = 1 mile.)

portions of the wall on the seaward side, in the shape of low mounds at the extremities of some of the small promontories.

At the point where the present waterfall is found (A in Fig. 11), this valley formerly bent

Plate LXIII

The sea-dissected valley of Wargery Water (Hartland District).

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a little more to the North, and ran parallel to the coast. While the landward wall has remained intact, the sea has captured nearly the whole of the opposite wall, with the exception of the low mounds of Screda Point and Hartland Quay. At one time, no doubt, this stream flowed out on to Warren Beach (B in Fig. 11), near the remains of the old pier at Hartland Quay. Remnants of its seaward wall can still be traced in the rocky hillock in front of Hartland Quay Hotel. Further, a considerable amount of the floor of the valley has also been washed away between Hartland Quay and Screda Point (Fig. 11). Between the present fall and Screda Point some of it still remains, though the sea has cut great rifts into it, some of which are seen in Plate LXIII, which also shows fragments of the seaward walls in the form of mounds at the end of the promontories. One of these rifts has captured the waters of the stream (at A, Fig. 11) and initiated the present waterfall. Thus not only has the real termination of this stream been beheaded, but its valley has been cut into in more than one place.

ST. CATHERINE'S TOR.

St. Catherine's Tor has already been fully described (p. 125, Plate XXXV). It is the seaward wall of a former tributary of Wargery Water flowing North-east, the greater portion of which

has become cut off by the sea, only a few yards of the lower part remaining. The outer face of the seaward wall is being rapidly cut into by the sea, but the inner side is still intact, and the height of the wall has not been appreciably lowered by marine erosion.

SMOOTHLANDS.

Further up the same coast near Hartland Point, the termination of Titchberry Water, the first stream South of the Point, has become completely isolated from the rest of the valley, and forms a good illustration of a sea-dissected valley (Frontispiece and Text-fig. 12). The isolated mouth of this stream is known as Smoothlands, and its principal features have been already described on p. 117. The history of this part of the valley appears to have been briefly as follows.

At one time the course of this stream, at a point which lay considerably seaward of the present waterfall and canyon, took a sharp turn (C in Fig. 12) from nearly due West to South-west, and its waters reached the sea near Dame Hole Point (A in Fig. 12). Its seaward termination, now cut off from the rest of the valley, then ran parallel to the shore-line and close to it. The sea attacked the right-angle bend (C in Fig. 12) and cut through it completely, and has since hollowed out the little cove seen in the Frontispiece. This event took place a long time ago. Titchberry Water then ended in a coast fall, somewhere between

D and C in Fig. 12. Since then it has cut back the canyon D–E, and the fall itself has retreated to E.

The sea-dissected portion, known as Smoothlands, cut off by the sea at both ends, is still

FIG. 12.—A map of Smoothlands, the ancient termination of Titchberry Water. A–B, the remains of the old valley; B–D, area removed by sea erosion; D–E, present canyon; E, present fall. The dotted line indicates the former course of the stream. The contour lines are 50 feet apart. (Scale, about 5 inches = 1 mile.)

in good preservation and offers an interesting study. The steep landward wall and the bottom of the valley are quite intact. The seaward wall has been considerably reduced in height by landslips on the seaward side, as the result of marine denudation. The sea is also rapidly eroding this wall, just as in the case of St. Catherine's Tor (p. 125), but

it has not yet cut through it. The bottom of the valley, 700 yards in length, now possesses no definite stream, though it is marshy in places, and after wet weather a trickle of water flows over the cliff at one of the numerous gullies cut by the sea in the southern end of Smoothlands. The floor of Smoothlands is still fifty feet above sea-level.

CROCK POINT.

The almost square area of nearly level land at Crock Point, close to Lee Mouth, and about half-way between Lynton and Woody Bay, may be a portion of a sea-dissected river valley, though in this case the fact is not so obvious as in the instances just discussed. Whatever may have been its origin, the occurrence of such an area of level cliff in this district is very remarkable, and is seemingly difficult to account for on any other hypothesis. For this comparatively flat surface, of about 900 square feet, appears, suddenly as it were, as we traverse a coast-line, in which cliffs, typically of the Hog's-back variety, stretch without a break for many miles to the West, and, apart from the exceptional case of the Valley of Rocks, which is only a variety of the same type, to the East also.

The sea erosion at Lee Mouth has undoubtedly been very great, and one possible explanation may be that the Lee, near its present mouth, at one time swept round parallel to the coast in a large bend towards the North-west, and that the sea

managed to cut through its valley at the point where this curve commenced. The level ground in front of Lee Cottage may be part of the old southern wall of the valley, but this, and the whole of the valley floor, have disappeared completely to the Westward as we pass along Rooks Cleave Plantation until we reach Crock Point. Here, possibly, the seaward portion of the level ground may represent part of the old valley floor of the Lee, and the landward side part of its southern wall, while the corresponding wall on the North may have been completely undermined and denuded by marine erosion. Thus the Lee may have formerly ended in a waterfall, on the west side of Crock Point, looking towards Woody Bay, but this has long ago been cut away by the sea.

Another possible explanation of this flat stretch of cliff is that it may be all that remains of a tributary of the Lee, flowing in from the North-west, the higher portion of which has completely disappeared beneath the sea, as well as its termination where it joined the Lee. Which is the correct explanation must be left an open question for the present, for the dissection of this old valley by the sea has reached such an advanced stage that it is very difficult to restore the former features of this locality.

Crock Point should certainly be compared with Smoothlands (p. 234) near Hartland Point. What we see here to-day may be only a more advanced stage in the dissection of either the main, or a

tributary, valley, a stage at which no doubt Smoothlands will also eventually arrive. There does not appear to be any evidence that the present state of affairs at Crock Point can be explained on the theory of a landslip having taken place here many years ago. The features of an ancient landslipped cliff may be studied at many points in Devon and Cornwall, particularly at the Dizzard (p. 154). They are quite distinct from those observed at Lee Mouth. On the other hand, the supposition that we are dealing here with an advanced stage in the erosion of a sea-dissected valley appears to explain the facts, especially in view of the other examples to be met with along this coast.

WATERMOUTH.

We have already described the peculiarities of the sea-drowned termination of the stream entering the Bristol Channel at Watermouth, between Ilfracombe and Combe Martin (Plate XI). One of the special features of Watermouth is that the end of the valley lies parallel to the coast, and that the sea is rapidly attacking the North-east wall, known as the Warren. The sea has driven several large clefts into this wall. One of these has cut completely through it, and isolated Sexton's Burrow as an island. The sea has also carved out another part of the wall, as an island known as Burrow Nose. But what is more interesting still

is that at Small Mouth, close to Watermouth cave, a great cleft (which is well seen from the footpath from Watermouth to Broad Strand) has been driven into the valley, and now reaches within a few yards (perhaps fifty) of the stream, at a point considerably inland from its sea-enlarged mouth. If this cleft or sea-cut gully advances further, the stream will be captured eventually, and the termination of the valley will be completely cut off, as has already happened at Smoothlands and near Hartland Quay. At Watermouth, however, the stream has reached base-level, while in the Hartland District, the dissected valleys are still far above sea-level.

The cases above mentioned are the most striking instances of sea-dissected valleys to be found along these coasts. There are, however, other valleys, the terminations of which, although not quite parallel with the trend of the coast, yet form an acute, and not a right angle, with the cliff-line. The lower portion of the East Lyn Valley at Lynmouth, and the Valley of Rocks at Lynton, are examples which we have already discussed (p. 42 and p. 43). In such cases the wall of the valley on the seaward side is naturally being eroded by the sea, though the sea has not yet cut through it into the floor of the valley. We see here the initial stages in the dissection of such valleys as we have described in the present chapter.

APPENDIX I

AN INTRODUCTION TO THE STUDY OF THE ROCKS.

Rock. THE term "rock" is employed by geologists in a sense somewhat different from that in which it is used in ordinary speech. It is applied to any mass of mineral matter, which forms a constituent part of the earth's crust, whether this mineral matter is hard and "rocky," or so soft that it can be dug with a spade. Sand and clay, for instance, are as much rocks in the geological sense as are the hardest granites.

Sections. The rocks forming the crust of the earth are, as a rule, entirely hidden from view by soil and vegetation, or by the waters of the ocean, or by snow and ice. They are, however, seen in these cases in which, by the agency of nature or man, the surface crust has been, as it were, sawn through, so as to expose what is called a "section." Railway cuttings and quarries are examples of "artificial sections," whereas "natural sections" occur on a particularly grand scale in sea-cliffs. "Cliff sections" are shown in many of the photographs illustrating the present volume.

Rocks fall naturally into two great classes—*Igneous* and *Sedimentary*, according to their origin.

Igneous rocks. Igneous rocks have their origin deep in the earth's crust. The temperature here is so high that vast masses of mineral matter are kept in a molten state, and, in times of volcanic activity, penetrate through cracks in the solid crust, and harden on, or near, its surface. *Granite* and *basalt* are characteristic examples of such igneous rocks. In North Devon and Cornwall, igneous rocks are, however, almost entirely absent.

Sedimentary rocks. The sedimentary rocks, on the other hand, have been laid down under water, in many cases on the beds of oceans or lakes. Unlike the igneous rocks, they are stratified—that is to say, they consist of a series of layers, one above the other, or, as the geologist terms them, *strata*. *Strata.* Such stratified deposits are being formed to-day. It is familiar to every one that the waters of rapidly flowing rivers are often quite turbid with suspended particles of sand or mud. When the river enters the sea or a lake its rate of movement is at once retarded, with the result that the waters have no longer the power to hold up their load of mud or sand. *Deposition.* The sediment is gently deposited on the floor of the sea or lake, and thus builds up, layer by layer, a stratified bed.

Four chief types of sedimentary rock are met with in the area discussed in this volume—

Sandstones. 1. *Sandstones*, or rocks produced by the consolidation of a sandy or gravelly deposit, composed essentially of *silica*. Coarse sandstones, whose component fragments are sharp and angular, are known as *grits*. Grits.

Shales. 2. *Shales*, or rocks produced by the consolidation of clayey mud or silt. They consist essentially of silicates of alumina, and split easily along the bedding planes.

Slates. 3. *Slates*, or shales in which the physical characters of the original deposit have been altered by earth pressures, so that they split along new planes, termed cleavage planes, distinct from the original bedding planes.

Limestones. 4. *Limestones*, or rocks consisting essentially of carbonate of lime.

Dip. As originally laid down, the sedimentary rocks were approximately horizontal, but owing to earth movements, subsequent to their formation, they have often become inclined at various angles. In such cases the angle which the bed makes with the horizontal is known as the *dip*, and its direction is indicated by reference to the points of the compass, *e.g.* a bed may be dipping 30° N.

Strike. The line of direction across country of an inclined bed is known as the *strike*, and the strike is always at right angles to the dip (see Fig. 9). The strike is, however, more accurately defined as the intersection of the plane of the *surface* of an

inclined bed with a horizontal plane. The strike of a bed is described by reference to its compass bearings, *e.g.* a bed may strike N.E. and S.W. The term strike is sometimes confused with *outcrop*. *Outcrop.* The latter is the actual space occupied at the earth's surface by an inclined bed, whereas the strike is simply a direction, and the outcrop may or may not coincide with the strike.

Stratified rocks commonly show signs of deposition in layers. The planes separating strata, such as alternate beds of sandstone and shales, are spoken of as lines of stratification or bedding planes, and *Bedding planes.* those, between the layers of a single bed or stratum, as lines of lamination. Other crack-like lines of separation or planes of weakness occur at right angles to the lines of stratification. These are spoken of as *joints*, and are due to the natural *Joints.* shrinkage of the rock during its consolidation. Two sets of joints commonly occur at right angles to one another, in consequence of which the rock tends to split into more or less cubical masses.

In a natural or artificial section of the rocks, *Faults.* other cracks, or fissures, or planes of weakness, in direction either vertical or inclined to the vertical, may often be seen. These, which are known as *faults* (Fig. 2), are lines along which the rocks on one or other side have been displaced, those on one side of the fault having slipped down relatively to those on the other. Further, where the dislocated

strata on one side have been forced up along the line of fracture, the plane is spoken of as a *thrust plane*, or *sliding plane*. It is thus obvious that the beds on either side of a fault or thrust plane are discontinuous (Fig. 2).

Thrusts.

Crust-creep.

The older strata are seldom horizontal, but have been inclined, or tilted, or even thrown into folds, as the result of earth-movements or *crust-creeps*. As the surface of the earth's crust has gradually cooled it has contracted, and has thus become wrinkled like the skin of a withered apple.

Folds.

The folds into which the strata are thrown are wave-like in form. The arched part of the undulation is known as an *anticline* (Fig. 2 and Plates I and III), and the trough which accompanies it a *syncline* (Fig. 2 and Plate II). The flanks are known as the *limbs*, and the summit as the *crest*. The central beds of the fold form the *core*. When the axis of an anticline and its accompanying syncline is oblique, an **S**-shaped or *sigmoidal fold* is produced. The central limb of the **S** may become elongated, drawn out, and finally broken, so that a *fault* or an *overthrust* results. The limbs of anticlines and synclines are often repeatedly folded, and to these minor undulations, if they are numerous and acute, the term *contortion* is applied.

Anticlines.

Synclines.

Sigmoidal folds.

Contortions.

Conformity.

When deposition has gone on in one place for a long time, a succession of beds is produced, all parallel to one another. The newer beds are then said to rest *conformably* upon the older. They may

have become bent and tilted by later earth movements, but the dip will be uniform throughout the strata, whatever the angle may be. Where, however, a series of beds has been raised above sea-level, and tilted out of the horizontal by earth movements, but eventually again depressed below the ocean, a fresh succession of beds will be deposited upon the original layers. In this case, however, the newer horizontal beds will not be laid down parallel with, or conformable to the old tilted series. In other words, the two series of beds will dip at different angles, and the upper is said to rest unconformably upon the lower. The plane of contact of two such series of rocks is spoken of as a "*junction*." *Unconformity.* *Junction.*

The atmospheric agencies, such as wind, rain, and frost (see also p. 179), are constantly breaking up and washing away the surface of the earth's crust, especially in the case of the higher land, and tending to reduce it to sea-level. This process is known as *denudation*. The materials removed from the land are deposited on the floors of the ocean, and thus deposition is always a corollary of denudation. Sometimes the greater part of a series of beds may have been denuded away, leaving only an occasional patch resting on the older rocks beneath. Such a patch of newer rock, surrounded on all sides by older rock, is known as an *outlier*. The reverse case, in which an isolated patch of older rock is surrounded by newer strata, is called an *inlier*. *Denudation.* *Outlier.* *Inlier.*

Erosion.

Surface changes of great importance are also brought about by the action of rivers. Every river is constantly wearing down its channel, by means of the friction of the transported debris against its bed. This process is called *erosion*, and is a special form of denudation. The transporting power of a river depends on the velocity of its current, which, again, depends on the slope of the bed. When the bed has been cut down until the gradient is almost horizontal, erosion practically ceases, as the river then flows too slowly to carry debris. It is then said to be at *base-level.*

Base-level.

Marine erosion.

The sea is also an active agent in the erosion of the land, as is fully explained in Chapter VII, on marine erosion.

Subdivisions of the sedimentary rocks.

The sedimentary rocks are classified according to their relative geological age, as exhibited by the evolution of the fossils which they contain. The primary groups are threefold: Palæozoic (the oldest), Mesozoic, and Tertiary (the newest). The chief subdivisions of these great groups are in order of age—

Palæozoic: Pre-Cambrian (oldest), Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Permian.

Mesozoic: Triassic, Jurassic, Cretaceous.

Tertiary: Eocene, Oligocene, Miocene, Pliocene, Pleistocene, Recent (newest).

(For other technical terms explained in the text, see Index.)

APPENDIX II

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(*Where several references are given under one heading the most important is indicated by heavy type.*)

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OF
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BY
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